

DETERMINING THE ANTHROPOMETRIC CHARACTERISTICS OF ADULT MALE  
POPULATION OF TURKEY

by

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## **ABSTRACT**

### **DETERMINING THE ANTHROPOMETRIC CHARACTERISTICS OF ADULT MALE POPULATION OF TURKEY**

Ergonomics briefly can be described as “human-centered” design. Anthropometry, the science of human body measurements, plays a major role in ergonomic design. Thus, designers must be familiar with anthropometric data and their applications so that they can design work systems, machines, equipment, tool, proper sizing of buildings, clothing and consumer products to achieve safe and efficient operations and/or use. Anthropometric data may show variation among nationalities and races. Hence, an anthropometric database is a need for every nation. Although there are a number of studies on the anthropometry of population of Turkey, most of them lack in various aspects to establish a valid and usable anthropometry database for the population of Turkey. Therefore, the main objectives of this study are as follows: (i) to generate an up-to-date anthropometric database of adult male population of Turkey, (ii) to investigate the effects of age and occupation on body dimensions, (iii) to compare the results with past male anthropometric data of Turkey and with other nationalities, and (iv) to investigate the dimensional changes over time. For the purpose, 65 static and dynamic body dimensions were taken from 250 adult males ages from 18 to 70 yrs. Sampling is done in a stratified manner including subjects from seven regions of Turkey. Subjects were divided into two occupational and five age groups. As a result of this study, 65 body measures of adult male population of Turkey were statistically determined. Average stature and weight were found as 171.5 cm and 76.6 kg, respectively. Results also indicate that stature and other vertical body dimensions decreases with age significantly, proving the secular trend. Also, nonmanual group was found significantly heavier than the manual group. A comparison with 1980s male data indicates that, on average, stature increased 3 cm and weight increased 8 kg. The comparison results with other nationalities indicate that anthropometric data of the male population of Turkey, in general, is similar to the some Southern Europeans and Americans in the USA, greater than Southern Asians and lower than Northern Europeans.

## ÖZET

### TÜRK YETİŞKİN ERKEK NÜFUSUNUN ANTROPOMETRİK VERİTABANININ OLUŞTURULMASI

Ergonomi, kısaca, “insan merkezli” tasarım olarak tanımlanır. İnsan vücut ölçüm bilimi olan antropometri, ergonomik tasarımda ana rol oynar. Bu nedenle, tasarımcılar antropometrik veriler ve bunların kullanımlarına aşina olmalıdır ki güvenli ve verimli operasyonu başarmak ve/veya kullanmak için çalışma sistemlerini, makinaları, ekipmanları, araçları, binaların boyutlarını, tekstil ve tüketici ürünlerini tasarlayabilsinler. Antropometrik veriler, uuslar ve ırklar arasındaki değişimi gösterebilir. Bu nedenle, antropometrik veritabanı, her ulus için bir ihtiyaçtır. Türk nüfusu için yapılmış birçok çalışma olmasına rağmen pek çoğu Türk nüfusu için uygun ve kullanılabilir bir antropometrik veritabanı kurmak için gereken özelliklerden yoksundur. Bu nedenle, bu çalışmanın ana amaçları şunlardır: (i) yetişkin Türk erkek nüfusu vücut ölçüleri için güncel veritabanını ortaya koymak, (ii) yaş ve meslek faktörlerinin vücut ölçüleri üzerindeki etkisini araştırmak, (iii) sonuçları Türk ulusu ve diğer milletler için daha önce yapılan çalışmalarla karşılaştırmak ve (iv) zaman içerisinde gözlenen değişimi ortaya koyabilmek. Bu amaçla, 18-70 yaş arası 250 kişilik örneklemden statik ve dinamik toplam 65 adet vücut ölçüsü alınmıştır. Örnekleme, Türkiye’nin yedi bölgesinden tabakalandırılmış metodla yapılmıştır. Örneklem, 2 meslek ve 5 yaş grubuna bölünmüştür. Bu çalışmanın sonucu olarak, Türk yetişkin erkek nüfusundan alınan 65 vücut ölçüsü, istatistiksel olarak tanımlanmıştır. Ortalama boy ve kilo değerleri, 171.5 cm ve 76.6 kg bulunmuştur. Sonuçlar göstermiştir ki, boy uzunluğu ve diğer dikey vücut ölçüleri yaşla birlikte önemli ölçüde azalmıştır; bu durum da seküler trendi doğrulamaktadır. Ayrıca, hafif işlerle çalışan insanlar ağır işlerde çalışanlara göre önemli ölçüde daha ağır bulunmuştur. 1980 yılındaki erkeklere ait verilerle yapılan karşılaştırma göstermiştir ki, ortalama olarak boy 3 cm, kilo 8 kg artmıştır. Diğer uluslarla yapılan karşılaştırma sonuçları da şunu göstermiştir ki; Türk erkek nüfusunun antropometrik ölçümleri genel olarak Güney Avrupalı ve Amerikalılar ile benzerken, Güney Asyalılar’dan büyük ve Kuzey Avrupalılar’dan küçüktür.

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## LIST OF ACRONYMS/ABBREVIATIONS

|                         |                                           |
|-------------------------|-------------------------------------------|
| ANOVA                   | Analysis of variance                      |
| BMIP                    | Body mass index prime                     |
| cm                      | Centimeter                                |
| diff                    | Difference                                |
| Dist.                   | Distribution                              |
| ht                      | Height                                    |
| kg                      | Kilogram                                  |
| N/A                     | Not available                             |
| SE                      | Standard error                            |
| std. dev.               | Standard deviation                        |
| yrs                     | Years                                     |
| CV                      | Coefficient of Variation                  |
| Meas.                   | Measurement                               |
| anthro meas             | Anthropometric Measurement                |
| BM                      | Body mass (kg)                            |
| Stature (e)             | Stature (erect)                           |
| Stature (n)             | Stature (normal)                          |
| Eye ht (e)              | Eye height (erect)                        |
| Eye ht (n)              | Eye height (normal)                       |
| Acr. (shld) ht (e)      | Acromial (shoulder) height (erect)        |
| Acr. (shld) ht (n)      | Acromial (shoulder) height (normal)       |
| Elbow ht (n)            | Elbow height (normal)                     |
| Fngtip ht (n)           | Fingertip height (normal)                 |
| Th-tip ht (n)           | Thumb-tip height (normal)                 |
| Fist(gr.ax, knck)ht (n) | Fist (grip axis, knuckle) height (normal) |
| Waist ht (n)            | Waist height (normal)                     |
| Vertical grip rch       | Vertical grip reach                       |
| Vertical th-tip rch     | Vertical thumb-tip reach                  |
| Vertical fngtip rch     | Vertical fingertip reach                  |
| Forward grip rch        | Forward grip reach                        |

|                           |                                             |
|---------------------------|---------------------------------------------|
| Forward th-tip rch        | Forward thumb-tip reach                     |
| Forward fngtip rch        | Forward fingertip reach                     |
| Span                      | Span                                        |
| Elbow span                | Elbow span                                  |
| Chest (bust) depth        | Chest (bust) depth                          |
| Chest (bust) brt          | Chest (bust) breadth                        |
| Stand. e-to-e brt         | Standing elbow-to-elbow breadth             |
| Shld-elbow lgt            | Shoulder-elbow length                       |
| Shld-fngtip lgt           | Shoulder-fingertip length                   |
| Shld-fist (grip axis) lgt | Shoulder-fist (grip axis) length            |
| Foot lgt                  | Foot length                                 |
| Foot brt                  | Foot breadth                                |
| Sit. ht(e)                | Sitting height(erect)                       |
| Sit. ht (n)               | Sitting height (normal)                     |
| Sit. eye ht (e)           | Sitting eye height (erect)                  |
| Sit. eye ht (n)           | Sitting eye height (normal)                 |
| Sit. acr. (shld) ht (e)   | Sitting acromial (shoulder) height (erect)  |
| Sit. acr. (shld) ht (n)   | Sitting acromial (shoulder) height (normal) |
| Sit. elbow rest ht (n)    | Sitting elbow rest height (normal)          |
| Knee ht                   | Knee height                                 |
| Popliteal ht              | Popliteal height                            |
| Buttock-knee lgt          | Buttock-knee length                         |
| Buttock-popliteal lgt     | Buttock-popliteal length                    |
| Thigh clearance           | Thigh clearance                             |
| Buttock-Leg Lgt           | Buttock-Leg Length                          |
| Sit.vertical grip rch     | Sitting vertical grip reach                 |
| Sit.vertical th-tip rch   | Sitting vertical thumb-tip reach            |
| Sit.vertical fngtip rch   | Sitting vertical fingertip reach            |
| Sit.forward grip rch      | Sitting forward grip reach                  |
| Sit.forward th-tip rch    | Sitting forward thumb-tip reach             |
| Sit.forward fngtip rch    | Sitting forward fingertip reach             |
| Head circumf              | Head circumference                          |
| Head lgt                  | Head length                                 |

|                         |                                         |
|-------------------------|-----------------------------------------|
| Head brt                | Head breadth                            |
| Ment-sellion (face) lgt | Menton-sellion (face) length            |
| Bizygomatic (face) brt  | Bizygomatic (face) breadth              |
| Neck circumf            | Neck circumference                      |
| Chest circumf           | Chest circumference                     |
| Waist circumf           | Waist circumference                     |
| Hip brt (sit.)          | Hip breadth (sitting)                   |
| Sit. e-to-e brt (n)     | Sitting elbow-to elbow breadth (normal) |
| Shld biacr. brt         | Shoulder biacromial breadth             |
| Shld bideltoid brt      | Shoulder bideltoid breadth              |
| Hand lgt                | Hand length                             |
| Hand brt                | Hand breadth                            |
| Palm lgt perp           | Palm length perpendicular               |
| Index finger lgt        | Index finger length                     |
| Hand circumf            | Hand Circumference                      |
| Wrist circumf           | Wrist circumference                     |

## 1. INTRODUCTION

Ergonomics (or human factors) is the scientific discipline concerned with the understanding of the interactions among human and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance (International Ergonomics Association (IEA) Executive Council, 2000).

Ergonomics is an applied science and engineering discipline which produces and integrates knowledge from the human sciences and engineering to match jobs, products, environment and technological systems to the human physical, mental abilities and limitations (Ekşioğlu, 2011). In doing so it seeks to safeguard safety, health and well-being whilst optimising efficiency and performance (ISO 15535, 2007). In other words, ergonomics is concerned with protecting workers from serious physical or mental harm, maximizing health and safety and well-being, optimizing performance and efficiency, maximizing productivity and quality and maximizing product usability and user acceptance. Applications range from the design of work areas including office furniture, automobile interiors, and aircraft cockpits to the disposition of switches and gauges on the control panels of machinery to determining the size, shape, and layout of keys on computer terminals and character height, color, and clarity on video displays (Pheasant, 2000).

Ergonomics became formalized during World War II when the military endeavored to design equipment that would fit their soldiers' needs. A notable case involved Lieutenant Alphonse Chapanis redesign of aircraft controls. By applying ergonomic principles, he was able to increase control panel ease-of-use and reduced the number of crashes that had, until then, been attributed to pilot error (Kroemer and Grandjean, 1997).

As ergonomics continued to evolve, two different fields emerged as engineering ergonomics which is the science of setting up work spaces, designing tools, equipment, and furniture with a focus on the physical mechanics of work, and cognitive ergonomics which is actually an analytical approach that considers the thought processes, mental workload, and decision making processes and focuses on creating training programs and even

software that will improve job performance. When both cognitive and engineering ergonomics are combined, it is referred to as holistic ergonomics (Eastman Kodak Company, 1983).

As a general comment, ergonomics is concerned with the design of equipment and by extension with the design of artifacts and environments for human use. If an object is to be used by human beings, it is presumably to be used in the performance of some purposeful task or activity (Pheasant, 2000). By this way, the fundamental principle of ergonomics is fit to the task to the human (Kroemer and Grandjean, 1997).

Anthropometry is an important branch of ergonomics which deals with body measurements, particularly with measurements of body size, shape, strength, mobility and flexibility and working capacity. Humans are variable (in dimensions, proportions and shape as in all other characteristics), and user-centered design requires an understanding of this variability (Pheasant, 2000). Since the components of user-centered design are product, user and the task, then the variation among these can result in the problematic design. Then, in order to design workspaces, safety equipment and personal protection tools considering the differences between the characteristics, abilities, and physical limits of any particular human body which resulting in effective design for high performance and productivity, anthropometric data are used. (Klamklay *et al.*, 2008)

The main aim of this study is to obtain the anthropometric data for the adult male population of Turkey. In addition, the effects of age and occupation on the anthropometric characteristics are investigated.

The thesis is organized as the following: Chapter 2 includes a literature review of previous studies that are conducted on the anthropometric characteristics of the male population. In Chapter 3, the objectives and rationale behind the study are mentioned. In Chapter 4, the methodology of the study is explained in details. Chapter 5 demonstrates the general and statistical results of the study in details. In Chapter 6, the discussion on the results is included. Moreover, in this chapter, comparisons with other studies in literature are involved. In the last chapter, the conclusions of the study are mentioned.

## **2. LITERATURE REVIEW**

### **2.1. Overview**

In this section, general information about anthropometry in terms of its types, ergonomic criteria, related ISO standards, also secular trend and anthropometric measurements including their techniques, anatomic concepts and dimensions which are used in this study given in details. In addition, the studies that are conducted on anthropometric measurements of a number of populations are included.

### **2.2. Anthropometry Defined**

Anthropometry literally means human (anthro) measurements (metric). It is the measurement of size and proportions of human body, as well as parameters such as reach and visual range capabilities. Accurate data on height, weight, limb, and body segment sizes are needed to design items ranging from clothing, furniture, automobiles, buses, and subway cars to space shuttles and space stations. Anthropometry enables us to properly size items, including system interfaces, to "fit" the user (FAA Human Factors, 2011).

Anthropometry can be considered as the analysis of body characteristics and the space in which the person functions, e.g. reach limits and clearances for movement. Thus, it is important for a variety of professional disciplines. In product design, anthropometry is important since both usability and safety require a close fit between people and their environment. Automobile design can be given as an example because it is important to make sure that people with a range of statures can have an adequate field of view through windows and mirrors, reach the pedals and hand controls, fit comfortably in the seats and not be exposed to avoidable safety risks in collisions (Kroemer, 1987).

#### **2.2.1. Types of Anthropometry**

Anthropometry can be divided into two types as static anthropometry and functional (dynamic) anthropometry (Steinfeld *et al.*, 2002).

2.2.1.1. Static (Structural) Anthropometry. It concerns basic dimensions of human body in standing and sitting measurements. In other words, static anthropometry focuses on body measurements at rest including overall dimensions like stature and weight, scales of links or circumferences as wrist to elbow, knee to hip, circumference of head and measurement of specific landmarks in reference to some other point, like the floor.

2.2.1.2. Dynamic (Functional) Anthropometry. It focuses on task oriented measurements. In other words, functional anthropometry is interested in the measurements of the body in motion like the reach envelope of seated work, the movement of body parts in relationship to one another or the space required to turn a wheelchair. It includes reach, clearance, volumetric data that depend on the characteristics of a task.

For static anthropometry, only the body segment lengths in fixed position are considered in workplace design. On the other hand, according to the dynamic analysis, acceptability of design is related to the the need to move the body from one position to another, as well as the reach and clearance considerations (Kroemer, 1987).

## **2.2.2. Factors Affecting Anthropometry**

The analysis of weights and sizes of body parts is directly related to anthropometry. By this context, there are three major factors that affect the variability in body characteristics: gender, age, and race or ethnicity (Bhattacharya and McGlothlin, 1996).

2.2.2.1. Gender Variation. It is an important criterion in workspace and workstation design. Size and shape differences between the genders have been poorly understood or ignored in design procedures. When men and women are nearly the same in height and weight, women are slightly larger on the average for a number of important workspace dimensions, particularly hip-related dimensions that are important in seated workstation design (Bhattacharya and McGlothlin, 1996).

2.2.2.2. Age Variation. It is common knowledge that adult body size and shape alters with age. In other words, body composition and size change through ageing process. Because of this reason, in order to have an accurate analysis about body size changes, longitudinal

studies are needed in which measurements are repeated periodically on the same individuals over their adult lifetime. Historically, some short-term longitudinal data, usually over 5-10 year periods, that include dimensions have been collected (Bhattacharya and McGlothlin, 1996). Some of these studies are given in the section of anthropometric measurements.

2.2.2.3. Racial/Ethnic Variation. Ethnic difference or ethnicity refers to populations that can be identified in association with a geographic or national boundary as well as a social or religious population. A major component in the diversity to be found in the workplace of the 21st century is considered as racial/ethnic variation (Bhattacharya and McGlothlin, 1996). In other words, body characteristics alter depending on the demographic distribution of people. This may be related to difference between genetic characteristics or nutrition habits (Pennathur and Dowling, 2003).

2.2.2.4. Secular Trend (Variation). Secular trend is used to determine the changes in the characteristics of a population over time. It results from several reasons such as ethnic, geographical and socio-economic factors, and clearly nutritional changes have an important role as reflected by positive correlations between age at puberty onset and age at menarche and childhood body size. Changes in height, pubertal maturation, and childhood body size have all also been related to rate of weight gain in infancy, and there is growing evidence to suggest that this early postnatal period may represent an early window of susceptibility to long-term 'programming' of various outcomes in humans (Ong et. al., 2006).

In short, secular trend is a marker of the public health of the population as it changes over time and it provides insights into the link between growth and the environment (Cole, 2003). In addition, it can be concluded that there are some results of changes in the characteristics of a population over time through childhood, puberty and adult as following:

- Increase in weight and stature values of children,
- Untimely pubertal maturation through menarche at earlier ages as puberty period,
- Increase in adult stature; and also gradual decrease at their older ages.

According to Tanner (1981), during approximately the last hundred years in industrialized countries, and recently in some developing ones, children have been getting larger and growing to maturity more rapidly. Its magnitude is such that in Europe, America and Japan it has dwarfed the differences between occupational groups.

Tanner (1981) emphasizes that in European countries, from about 1900 to the present, children in average economic circumstances have increased in height at ages five to seven years by about 10-20 mm per decade. In 1900s, working boys aged 10 years averaged 121 cm in height and also those aged 18 years averaged 160 cm. Nevertheless, in 1980s, the former was 140 cm and the latter was 175 cm.

Also, there are some studies about growth trend of Japanese children. In one of these studies, the data of Tanner *et al.* (1981) show that from 1900 to 1940, the trend was less than 1 cm per decade. Then, in the decade between 1950 and 1970 for seven-year-old boys, the increase in stature was 30 mm per decade while it was 50 mm per decade for twelve-year-old. This means that the rate of increase had risen in time.

Next, the data of Tanner (1982) points out that the trend in Canada, the USA and Australia has been almost similar with Japan. On the average, the differences in the growth of children and adolescence in these countries are as following:

- 15 mm increase per decade in stature and 0.5 kg increase per decade in weight at five to seven years of age,
- 25 mm increase and 2 kg increase per decade during the time of adolescence,
- 10 mm increase per decade in adult stature.

On the other hand, for Swedish children, the trend was gradually stopping.

Kimura (1984) analyzed Japanese children and adolescences. According to these data, the estimated increase per decade in the two dimensions was 60 mm and 1.2 kg among males, and 50 mm and 1 kg among females, respectively, during these five decades. Thus, it is emphasized that the size of Japanese has increased progressively from decade to decade.

As a last point, according to Kimura (1984), after World War II, many researchers considered the influence of the poor wartime conditions on the growth and development of children. Results of all studies indicated a decrease in size. The poor living conditions during the war had a harmful effect on the growth of younger children, but girls had greater resistance to these conditions than boys. Also, it is underlined that recovery of stature, body weight, and chest depth in school children occurred most rapidly in large cities, followed by small cities, and then rural and mountain villages. As an instance, it is denoted that in some rapidly developing countries, a secular increase begun much later than in North America and Europe is continuing.

Clasessens and Lefevre (1992) investigated secular changes in anthropometric characteristics of 3514 physical education students at the Katholieke Universiteit Leuven (Belgium) from the academic years 1941-1942 and 1988-1989, dividing into nine groups. Table 2.1 shows some of results of this study.

Table 2.1 shows that there is not a significant difference on chest depth; on the other hand, weight and stature increase significantly.

Table 2.1. Means of body dimensions of first year physical education students between 1941 and 1988 by cohort.

| <b>Body Dimension</b>     | <b>1941-1946</b> | <b>1947-1952</b> | <b>1953-1958</b> | <b>1959-1963</b> | <b>1964-1968</b> | <b>1969-1973</b> | <b>1974-1978</b> | <b>1979-1983</b> | <b>1984-1988</b> |
|---------------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| <b>Weight (kg)</b>        | 65.5             | 66.6             | 68.1             | 68.2             | 68.3             | 67.8             | 69.1             | 69.2             | 69.7             |
| <b>Stature (cm)</b>       | 172.6            | 172              | 172.6            | 173.5            | 174.7            | 175.1            | 177.5            | 177.9            | 178.4            |
| <b>Sitting height</b>     | N/A              | N/A              | N/A              | 91.5             | 92.3             | 89.9             | 92.1             | 92.8             | 93.6             |
| <b>Biacromial breadth</b> | N/A              | N/A              | N/A              | 40.3             | 39.9             | 39.6             | 39.9             | 39.4             | 39.8             |
| <b>Chest depth</b>        | N/A              | N/A              | N/A              | 19.1             | 19.1             | 18.9             | 18.9             | 18.7             | 19.2             |
| <b>Hip circumference</b>  | N/A              | N/A              | N/A              | 93.2             | 93.6             | 92.6             | 91.7             | 90               | 89.9             |

In conclusion, according to the human biologists, social and environmental influences such as the improved nutritional quality of diet, the reduction of infectious disease by improved hygiene and health care, also urbanization, reduced family size and genetic factors such as heterocyst make the people grow more rapidly. All these changes can take a role in the change of body dimensions.

2.2.2.5. Other Factors. There are some other factors including smoking and drinking habits, frequency of sportive activities or geographical region that may be effective on anthropometric dimensions (Bhattacharya and McGlothlin, 1996). Historically by anthropologists, some of these factors were analyzed to check if there was an effect of factors on anthropometric measurements.

### **2.2.3. ISO Standards for Anthropometry**

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for whom a technical committee has been established has the right to be represented on that committee. The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Standardization of data procurement can be accepted as the most important objective of anthropometry. It shows the ways of comparing anthropometric data from different sources. This necessary requirement has been fulfilled by the international standardization of anthropometric data and processes. The types of standards relation to anthropometry is described in Table 2.2 (Seidl and Bubb, 2006).

To determine the human body measurements for technological design, ISO 7250 prepared by the SC3 Technical Committee ISO/TC 159 is so appropriate. ISO 7250 (the International Organization for Standardization about body measurement for technological design) standards provide a description of anthropometric measurements which can be

used as a basis for comparison of population groups. It is one of the most important standards, because it introduces an international harmonization of the body measurements. It introduces the most important body dimensions to be acquired. 55 body measurements and body mass are defined, based on detailed postures. For each of the body measurements, there is a clear-cut description (name and number), a sketch, a notation of the measurements and the recommended measuring method and the measuring instrument.

The basic list specified in ISO 7250 is intended to serve as a guide for ergonomists who are required to define population groups and apply their knowledge to the geometric design of the places where people work and live. This list is not intended to serve as a guide for how to take anthropometric measurements, but it gives information to the ergonomist and designer on the anatomical and anthropometrical bases and principles of measurement which are applied in the solution of design tasks (ISO 7250-1, 2008).

The body measurements defined in ISO 7250 does not unfortunately include all dimensions required in industry. Thus, additional dimension need to be included in comprehensive anthropometric studies.

Table 2.2. ISO standards for anthropometry.

|                    |                                                                                                                                                     |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>ISO 7250</b>    | Basic human body measurements for technological design                                                                                              |
| <b>ISO 8559</b>    | Garment construction and anthropometric surveys — Body dimensions                                                                                   |
| <b>ISO 14738</b>   | Safety of machinery-Anthropometric requirements for the design of workstation at machinery                                                          |
| <b>ISO 15534-1</b> | Ergonomic design for the safety of machinery-Part 1: Principles for determining the dimensions required for openings for whole body access openings |
| <b>ISO 15534-2</b> | Ergonomic design for the safety of machinery-Part 2: Principles for determining the dimensions required for access openings                         |
| <b>ISO 15534-3</b> | Ergonomic design for the safety of machinery-Part 3: Anthropometric data                                                                            |
| <b>ISO 15535</b>   | General requirements for establishing anthropometric databases                                                                                      |
| <b>ISO 15537</b>   | Principles for selecting test persons for testing anthropometric aspects of industrial product and designs                                          |

Some of the dimensions not included in ISO standards were selected from NASA standards given in a table of measurements and guidelines developed and published by the U.S. Department of Defense Ergonomics Working Group. Also, for the application of measurements, the information obtained from the American National Standards Institute (ANSI) was used (American National Standards Institute, 2010). By making such selection about anthropometric measurements, in this study, the usability of measurements to produce human oriented products and design workstation was thought.

### **2.3. Anthropometric Measurements**

The evaluation of body dimensions are followed by using static anthropometry which is related to basic dimensions of human body in standing and sitting measurements. These dimensions are affected by both major factors including gender, age and genetic factors, and specified aspects such as change in life styles and nutrition habits. Such an alteration leads to increase in requirement regular updating of anthropometric data collections in order to have an accurate analysis about body dimensions of a population as a general.

To evaluate anthropometric dimensions in a more precise way, techniques used while measuring and features of anatomic concepts incidental upon types of the measurements are important.

#### **2.3.1. Measurement Techniques**

Anthropometric measurements can be obtained by using two techniques as traditional methods and three-dimensional body scanning technology.

2.3.1.1. Traditional Techniques. Measurements are taken by using standard anthropometric equipments which are simple, quick, non-invasive tools including a weight scale, camera, measuring tape, anthropometer, spreading caliper, sliding compass, head spanner, stadiometer and grid planes. Classical anthropometric data provides information on static dimensions of the human body in standard postures (Kroemer and Grandjean, 1997).

Dimensions are taken in both standing and sitting positions. For standing measurements, the subject's body is placed in a defined upright straight posture, with the body segments at 180, 0, or 90 degrees to each others. In order to identify the body measurements, it is necessary to have landmarks of which to measure to and from.

While measuring, it is preferable to have the subject completely unclothed or with as little clothing as possible.

2.3.1.2. Three-Dimensional Body Scanning Techniques. When measuring a large number of locations on the human body, 3-D body scanning method can be more preferable. This technology is capable of extracting an infinite number of data types and measurements in which body shapes, angles, and relational data points are easily obtained. The 3D image taken after measuring the subject allows instant evaluation regarding validity of the scan; and the dimensions and shape data could be used repeatedly for various garments without the need for repeated measurement. The 3D scanning technologies used for body measurement extraction on today's market are based on various systems. Current body scanners are generally identified in three different types as [TC]2, Cyberware, and SYMCAD.

Simple anthropometric methods using measuring tapes and calipers are still being utilized to measure the human body. The methods are time consuming and often not accurate. With the development of 3-Dbody scanning, this technology allows for the extraction of body measurements in seconds. It also allows consistent measurements. However, there are a number of problems that exist with the adoption of this technology (Simmons, 2001).

- There are no standards published on the interpretation of measurements. Current standards for body dimensions like International Standards Organization (ISO) present traditional measurement techniques.
- There are some types of scanners, and significant variance exists in how each one of those capture specific body measurements. Until the data capture process of these measurements can be standardized or, at the very least, communicated among the

scanning systems, this technology cannot be utilized for its maximum benefit within the industrial design.

- There is an unwillingness of some scanner companies to share information about their scanning process. Some companies will give how the data capture occurs, how and what landmarks are used, and general information about their measurement extraction. These are the kinds of attitudes that cause barriers to be built, which could inhibit the growth of this technology.
- As another problem is the need of some scanners to require landmarking. Manually identifying landmarks is time consuming and, usually, full of error. Landmarking also violates the privacy of the individual. A human must come in contact with the subject's skin in order to find the landmark and to mark it. On the other side, another issue is that scanners that do landmarking automatically are most times making an educated guess as to the exact location of that landmark. Without being able to touch the subject's skin, absolute identification cannot be achieved.
- Also, for 3-D body scanning technique, subjects should be as possible as in their minimal clothes as much as possible in order to have more accurate measurements. In some cultures like in Turkey, it is difficult to meet such a demand.
- As a last challenge, 3D body scanning is a very expensive technology. This is because lighting parts and cameras are perishable, and this is required to be renewed periodically.

### **2.3.2. Anatomical Concepts**

In performing anthropometric measurements, some knowledge of human anatomy is essential, because almost all measurements are defined in terms of some body part or some specific location on a specified part. Subject being measured are directed to assume specific predefined positions. The standard preference point is the anatomical position, in which the person stands erect with arms at the sides and the palms of the hands facing forward. From this posture the descriptive terms that define the body's principal axes and the resultant planes are derived. From these planes, too, the basic terms which are used to describe the relative position or location of relevant points on the body structure are developed. The most commonly used terms are shown diagrammatically in Figure 2.1. Typically, the principal axes, X (front-to-back), Y (side-to-side), and Z (head-to-foot),

divide the body into three planes; sagittal, which divides the body into right and left parts (XZ); and transverse, which divides the body cross-sectionally (XY) (Bhattacharya and McGlothlin, 1996).

The relative positions of particular structures or features in or on the body are defined as follows (Bhattacharya and McGlothlin, 1996):

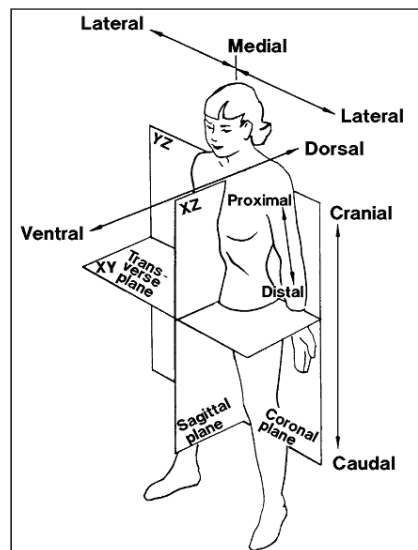


Figure 2.1. Terminology used to define position and location on the body.

- Anterior/Posterior indicates that structures nearer the front or ventral side are Anterior (+X) to those located nearer to the back or dorsal surface, which are posterior (-X).
- Medial/Lateral indicates that structures which are located nearer to the center of the body or the midsagittal plane relative to others are medial to those located away from the central body on the left (+Y) or right (-Y) side, which are lateral.
- Superior/Inferior indicates that structures located nearer the head are located superior (+Z) to those below, which are termed inferior (-Z). The heart is located superior to the kidneys.
- Proximal/Distal indicates that on the limbs, parts that are near the trunk are proximal whereas those farther from the body central are distal. A finger is distal to the elbow.

Frequently the points between which a given dimension is measured are actually drawn on the subject's skin by the anthropometrist. Such points are called landmarks.

Some landmarks are simply determined by a certain feature found in the topography of the body surface, e.g., the tip of a finger; others must be palpated and marked in a relation to skeletal architecture. The main landmarks are shown in the Figure 2.2.

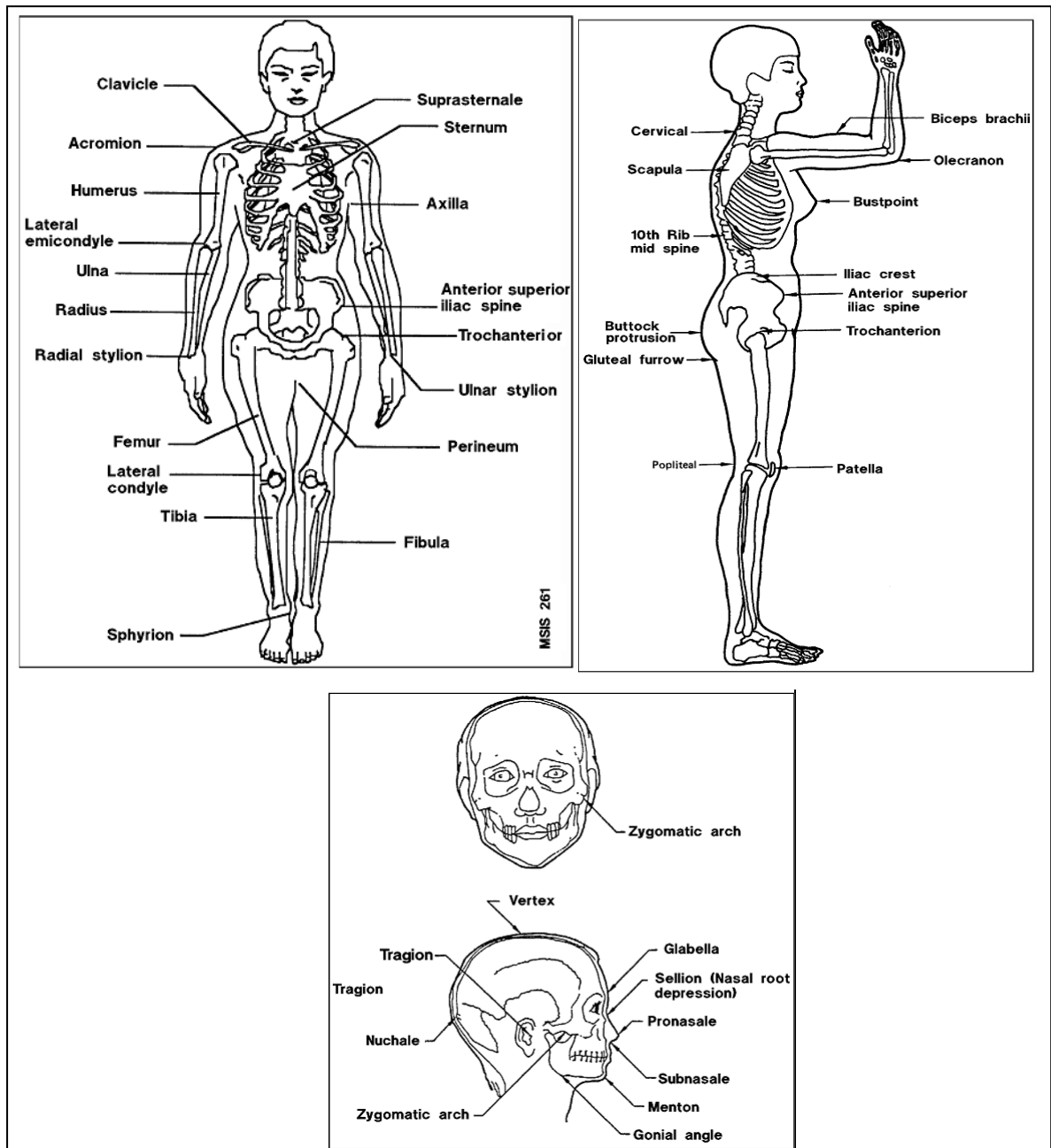


Figure 2.2. Selected skeletal landmarks used to define traditional anthropometric measurements (NASA-STD-3000, 1981).

### **2.3.3. Types of Measurements**

Anthropometric measurements are related to the characteristics of different parts of the body including height, weight, vertical and forward reaching positions, breadth and depth dimensions, and circumference at the waist, hip, and chest.

There are more than 300 measurements in anthropometry (Simmons, 2001). In literature, a number of surveys included 37 of these measurements (Pheasant, 2000). On the other hand, according to the standards in ISO 7250 (the International Organization for Standardization) that provides a description of anthropometric measurements which can be used as a basis for comparison of population groups, this number is not enough to reflect the whole dimensions required in product or workstation design.

## **2.4. Anthropometric Design Approaches**

There are four anthropometric design approaches (Ekşioğlu, 2011; Fernandez and Marley, 1998):

### **2.4.1. Design for the individual**

- It uses the anthropometric measurements for each person where it is important to design personal product.
- It is best design, but it can be expensive.

### **2.4.2. Design for adjustability**

- It considers designing for a range usually from the 5<sup>th</sup> percentile female value to 95<sup>th</sup> percentile male value of the target population which accommodates 95% of the total population. For 50/50 mixed male and female population, 5<sup>th</sup> percentile to 95<sup>th</sup> percentile accommodates 90 % of the target population.
- It is preferred for multiple users, but it can also be expensive. Some examples are design of auto seats, office chairs, stocking hats, etc.

### **2.4.3. Design for the extremes (Design for the smallest or the largest)**

- It is a design approach which considers designing for population extreme value (min or max). This value is commonly either for 5<sup>th</sup> percentile female or 95<sup>th</sup> percentile male depending on the design. For example, the designs of doorways, size of escape apparatus on military aircraft, strength of supporting devices (such as a trapeze, rope ladder, or workbench) considers 95<sup>th</sup> % the male values. On the other hand, the designs of shelf height, distance of control button from the operator and the required forces to operate them considers 5<sup>th</sup> % the female values.

### **2.4.4. Design for the average**

- This design approach is used where adjustability is impractical. Supermarket check-out counter and public seating can be given as examples.
- Also, it can be used where the design is non-critical. Door knob height and snack machine controls can be given as examples.

## **2.5. Anthropometric Design Procedures**

These steps should be followed to design in an accurate way as follows (Ekşioğlu, 2011; Kroemer, 1987):

- Step 1. The design parameter should be defined. Seat-to-roof dimensions in automobiles, handle size of a tool or tool operation force can be given as examples.
- Step 2. The corresponding anthropometric measures should be selected. Sitting height as a basic factor in seat-to-roof dimensions in automobiles, hand breadth for handle size of a tool or grip strength for tool operation force can be given as examples.
- Step 3. The population should be defined to use the equipment or facilities. Turkish civilians, Turkish Military, women, children, pilots, world populations, different age groups or persons on the wheelchair can be given as examples.
- Step 4. The design principle (whether the design must be for extreme individuals (minimal or maximal), for an adjustable range, or for the average) should be

determined. Seat height should be designed for a range, handle size of a tool should accommodate the largest extreme or tool operation force should accommodate the smallest extreme can be given as examples.

- Step 5. The percentage of the population should be selected to be accommodated when it is relevant. The values of 90%, 95% or whatever is relevant to the problem can be given as selected percentage values.
- Step 6. Anthropometric tables appropriate for the population should be located, and relevant values should be extracted.
- Step 7. Modifications (i.e., apply the correction factors) should be made when it is necessary. Shoe height, helmet or heavy clothing can be given as examples.
- Step 8. Critical dimensions should be testes with a mock-up, user testing, a virtual model, or a computer model to ascertain that they are compatible. There are some examples such as that the legroom clearance height needed for sitting persons with long lower legs may be very close to the height of the working surface determined from elbow height.

## **2.6. Anthropometric Studies**

### **2.6.1. Studies in Other Countries**

As mentioned, anthropometry is the science of measurement of body size (NHANES, 2007). Anthropometric data are found very important to design workspaces, safety equipment and personal protection tools considering the differences between the characteristics, abilities, and physical limits of any particular human body which resulting in effective design for high performance and productivity (Klamklay *et al.*, 2008). By this context, most of the nations have tried to generate their own anthropometric databases. Some of these studies are reviewed in the following.

There are some comparisons in literature. As one of these studies, Vecchio & Fox (1978) studied on the comparisons about 39 measurements for many countries by using the results of previous surveys. In this study, American adults, German flying personnel, Greek, Italian, Japanese, French, Turkish, Swedish and Korean pilots were compared. According to the results, the US and Swedish pilots were the tallest in all nations, and also,

from 1920s to 1970s, there were increases in stature and body mass of total population of these two nations.

The anthropometric measurements of French drivers between 18-60 years have been presented by Rebiffe *et al.* (1983) in order to investigate the distribution of their anthropometric characteristics.

For the anthropometric study of Irish people, Gallwey & Fitzgibbon (1991) measured 164 male workers who worked on the electronics, photographic machines, household goods and precision engineering manufacturing industries. Data was enabling for 11 measurements but there exists some estimates for the body dimensions. According to the results, there was a significant difference between the populations of Ireland and US, and American population is heavier.

The anthropometric measurements of Taiwanese women have been presented by Huang and You (1994). 300 women in 18-45 years were measured, and then the distribution of their anthropometric characteristics was shown.

For Italian population, Ravaglia *et al.* (1997) studied on the anthropometry. They measured 24 female and 33 male subjects of nonagenarians and 41 subjects of centenarians at 70-89 years with 15 measurements. In this survey, anthropometric values of both age groups were generally lower than published norms for 70-89-year-old American and European elderly people. However, differences were less marked when comparing Italian nonagenarians and centenarians with French and British people aged 85 years whereas it was over when comparing Italian subjects with American octogenarians and younger European elderly people.

The first study for the Poland elderly women was made by Jarosz (1999). The aim of this study was to present the anthropometric data of Poland women population. Also, in this study, there exist some comparisons between 20-59 years old and above 60 women.

Liu *et al.* (1999) studied on the American female workers of the maquiladora industry. 12 body dimensions were measured, and compared with anthropometric

characteristics of Mexican-American females and females in Colombia, Japan, Korea, and the US. The results showed that anthropometric characteristics for female maquiladora workers were significantly different from those of the Mexican-American females. On the average, the maquiladora females were 47 mm shorter in stature than Mexican-American females. The results also show that maquiladora females and Japanese females shared similar anthropometric characteristics.

Thirty different body dimensions including body mass of Norwegian light industry and office workers were measured in the survey of Bolstad *et al.* (2001). The male and female subjects were equally divided into two groups of 20-29 years and 30-39 years, respectively. There was no significant difference in stature between these two age groups; but, 30-39 aged groups were heavier than the 20-29 years-old.

In a survey by Prado-Leon *et al.* (2001), 50 anthropometric measurements of male and female Mexican primary school children age 6-11 years in the metropolitan area of Guadalajara were collected. The sample consisted of 4758 children (boys and girls). These data were compared to those of American, Cuban and Mexican children from other regions of Mexico. The results show that the body measurements of Mexican children in this study are different from those of American, Cuban, and other Mexican children, probably due to ethnic differences and the time lapse between the different studies.

In Mokdad's study (2002), 36 body dimensions of Algerian farmers were measured. Mean, variation measures, percentiles, and correlation coefficients between body dimensions were calculated. The results show that both stature and weight correlated significantly with many body dimensions. In addition, age affected height and body weight. Moreover, it was found that stature and weight have increased with time. Moreover, farmers in the 2000s were taller and heavier than farmers in the 1960s. Algerian farmers were also taller and heavier than farmers of many developing countries. However, when Algerians are compared with the farmers of developed countries, they are shorter and lighter.

Dangour *et al.* studied on the anthropometric status of Kazakh children in 1990s (2003). Using anthropometric data of children, from random samples collected in 1992,

1994 and 2000, they investigated changes in body size of 4.0–4.9-year-old children over the 8-year-study period. According to the results, between 1992 and 2000, there was no statistically significant change in body size of 4.0–4.9-year-old boys; but, 4.0–4.9-year-old girls became significantly smaller because of nutritional changes over time.

For the Mexican population, a number of subjects on 20-29 years and 60-85 years were measured by Pennathur and Dowling (2003). In this study, there were 2 age groups such as 20-29 and 60-85. By this way, the comparisons between previous studies were performed, and then change was observed.

Santos *et al.* (2004) studied USA population by measuring 8 body dimensions in terms of gender and age effects. This study shows that men were significantly heavier and taller than women in all age groups, whereas body mass index values were significantly higher in women than in men. All anthropometric variables showed a decrease in average values with aging in men and women.

Dewangan *et al.* (2005) collected the anthropometric dimensions of male farmers in the North Eastern region of India in age group of 20–30 years with 33 anthropometric measurements. These data were compared with studies in China, Japan, Taiwan, Korea, Germany, Britain and the USA. It was found that all the dimensions of Indian male farmers were lower than those of compared populations, even Chinese.

Yokota (2005) studied US army male soldiers for military design. According to the results, nose breadth and lip length were different between Blacks and Whites. The author emphasized that based on the sample reported; sizing and designing for the mixed groups are not necessary if anthropometric distributions of single racial groups comprising mixed groups are known.

The first comprehensive anthropometric measurement of Filipino manufacturing workers was performed by Jinky Leilanie Del Prado-Leon (2007) with 962 female and 843 male workers from manufacturing industry with 45 anthropometric measurements. According to the author, this study was a significant contribution to the Filipino labor force that is increasingly employed by both domestic and foreign multinationals.

Another study of Dewangan (2008) was related to again Indian agricultural workers. In this study, the collected data of Dewangan were compared with those of American, British, Chinese, Egyptian, Japanese, Korean, Mexican and Taiwanese female workers. As a result, it was found that values of body dimensions of tribal female workers from two north eastern states of India are lesser than those of eight other countries mentioned above. For example, in stature, Indian women are shorter by 9.27 cm as compared to American women.

In the study by Klamklay *et al.* (2008), there exist comparisons between the current anthropometric data of Thai population and the other existing ones. The survey was performed with 50 female and 50 male students with the age groups in 18-25 years. The study has shown that there were significant changes on the anthropometric characteristics of Thai population.

Mandahawi *et al.* (2008) were interested in only the hand measurements of Jordanian population in order to get information for the design of hand tools. In this study, significant differences between Jordanian and the other populations were observed. But, according to the authors, it was difficult to draw broad generalizations.

In another study, Mehta *et al.* (2008) studied the anthropometry of the Indian agricultural workers. In this study, the recommended seat dimensions for tractor operator's comfort were as follows: seat height of 380 mm, seat pan width of 420–450 mm, seat backrest width of 380–400 mm (bottom) and 270–290 mm (top), seat pan length of  $370 \pm 10$  mm, seat pan tilt of 5–71 backward and seat backrest height of 350 mm.

In the study of Baten *et al.* (2009), Argentina, Brazil and Peru populations were compared with each others. The results show that non-farm Brazil and Lima, Peru, have smaller height values. Also, Brazil made substantial progress in nutritional levels from the 1860s to the 1880s. Argentinean men were tall to begin with, but heights stagnated. The only exception was related to farmers and landowners, who benefited from the export boom.

The anthropometric measurements of Israeli males were obtained by Purundzhan and Borovsly (2009). This study examined temporal changes of body size and shape in two groups of Israelis as Ashkenazim and Sephardim over thirty years. According to the results, in the Ashkenazim, body length increased mostly between 1970 and 1985 while in the Sephardim, it decreased during the same period.

Coqueiro *et al.* (2009) tried to a cross-sectional, population-based household survey. A total of 1905 subjects (1197 women and 708 men) at their sixties were examined between 1999 and 2000 as selected by random sampling. According to the results, all anthropometric variables showed a decrease in average values with aging in men and women. The age of 70 years appeared to be the decisive moment for the main anthropometric differences observed. The values in the female group were higher than those in the male group for body mass index (BMI) and triceps skin fold thickness.

For the hand measurements, Imrhan *et al.* (2009) measured 51 female and 50 male adults from Bangladesh population with the average age of 41.3 years. According to this study, there was a significant difference in palm and finger segment lengths, breadths and depths between genders. These data are useful for the design or selection of hand tools, gloves, machine access spaces and hand-held devices.

In Mokdad and Al-Ansari's survey (2009), Bahraini students were measured. Results show a gradual increase from age 6 to 12 in all body dimensions. When compared with children from other nationalities, Bahraini children all have almost medium height and weight values.

The survey on Italian population was performed by Cereda *et al.* (2010). In this study, height can be estimated by using some other anthropometric dimensions in regression model. Also, body mass index (BMI), body surface area, fat-free mass and resting energy expenditure were calculated.

Chuan *et al.* (2010) studied the anthropometric data of the Singaporean and Indonesian populations. The data were mainly from university students. In total, 245 male and 132 female subjects from Indonesia, and 206 male and 109 female subjects from

Singapore were measured with 37 anthropometric measurements. The results show that Singaporeans have larger dimensions than Indonesians in general. On the other hand, Singaporeans and Indonesians subjects were found the part of the population which has largest values for almost all dimensions for both genders.

Dewangan *et al.* (2010) measured the stature and 9 other body dimensions of the 801 male Indian agricultural workers to estimate a total of another 20 body dimensions with simple linear regression equations. The authors emphasized that the increase in the anthropometric measurements for Indian farmers has resulted from the agriculture of the North Eastern region of India changing from traditional ways to settled cultivation.

A study by Serre *et al.* (2010) focused on child anthropometry, and measured 2000 French children for 8 body dimensions in order to get information especially head measurements for clothing industry and also lower extremity dimensions for design of school chair.

In summary, the main findings from the reviewed studies can be listed as follows:

- For Indian male farmers, in general, there are increase in anthropometric dimensions from year 2000 to 2010, showing secular trend.
- There is a significant difference in some of the anthropometric measurements between the populations of Ireland and US. According to the result, US population has larger dimensions.
- The values of body mass and stature of Algerian farmers are larger than many developing countries although they are smaller than developed ones.
- Singaporean populations have larger values in anthropometric dimensions than Indonesian population.
- For the population of Norway, there was no significant difference in stature between these two age groups: 20-29 and 30-39. However, 30-39 aged group was heavier than the 20-29 years-old.
- Age is a significant factor for the anthropometric characteristics of Thailand population such that there is increase in body dimensions with aging up to middle of 30s; and then there is a decreasing trend with aging.

- For Mexican population, there is a significant decrease in body dimensions with aging.
- For US population, the values of stature and body mass are significantly affected by gender and age. Men were significantly heavier and taller than women in all age groups, whereas body mass index values were significantly higher in women than those in men. All anthropometric variables showed a decrease in average values with aging in men and women.

In Table 2.3, some of the studies given above are explaining in details in terms of sample types, measurement equipments and factors analyzed.

Table 2.3. Information of some studies about anthropometric measurements of people in foreign countries.

| Source                                      | Country                | Sample type (n*)                                 | Equipment (Number of Dimensions)                                                                                                         | Age range (yrs) | Independent factors   | Age-groups                                                               |
|---------------------------------------------|------------------------|--------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|-----------------|-----------------------|--------------------------------------------------------------------------|
| <b>Rebiffe <i>et al.</i> (1983)</b>         | France                 | Drivers (250)                                    | Harpenden anthropometer, tape measure, calipers and anthropometers (37)                                                                  | 18-60 yrs       | Age                   | Overall                                                                  |
| <b>Gallwey &amp; Fitzgibbon (1991)</b>      | Ireland                | Workers (164 M)                                  | Harpenden anthropometer, a wooden base, a wooden seat (11)                                                                               | 17-58 yrs       | N/A                   | 17-58 yrs                                                                |
| <b>Ravaglia <i>et al.</i> (1997)</b>        | Italy                  | Stratified sampling (24 F, 33 M)                 | A sliding broad-brade caliper, a Holtain skin fold caliper (15)                                                                          | 70-89 yrs       | Gender, age           | Overall-Group1<br>Overall-Group2                                         |
| <b>Bolstad <i>et al.</i> (2001)</b>         | Norway                 | Light industry and office workers (199 F, 200 M) | Weighing scales, Harpenden anthropometers, measuring tapes, Digimatic sliding callipers, adjustable chairs and self-produced wooden (29) | 20-39 yrs       | Age, region<br>gender | Overall<br>20-29 yrs<br>30-39 yrs                                        |
| <b>Mokdad (2002)</b>                        | Algeria                | Farmers (514 M)                                  | A portable weighting scale, a squeeze dynamometer, and Harpenden standard anthropometer (36)                                             | N/A             | Age, region           | <25 yrs<br>25-45 yrs<br>>45 yrs                                          |
| <b>Santos <i>et al.</i> (2004)</b>          | USA                    | Stratified sampling (819 F, 411 M)               | A Harpenden pocket stadiometer, a SECA platform scale, a broad-blade caliper, a chair (8)                                                | 60-99 yrs       | Gender, age           | 60-64 yrs<br>65-69 yrs<br>70-74 yrs<br>75-80 yrs<br>80-84 yrs<br>>85 yrs |
| <b>Jinky Leilanie Del Prado-Leon (2007)</b> | Philippines            | Manufacturing industry workers (962 F, 843 M)    | Tape measure, a goniometer, calipers and anthropometers (45)                                                                             | N/A             | N/A                   | Overall                                                                  |
| <b>Dewangan <i>et al.</i> (2008)</b>        | India                  | Stratified sampling (400 M)                      | Anthropometer, a portable weighting scale, a wooden cone (76)                                                                            | 18-60yrs        | Age, region           | Overall                                                                  |
| <b>Klamklay <i>et al.</i> (2008)</b>        | Thailand               | Students (50 F, 50 M)                            | Campbell Caliper, Segmometer, Anthropometric Tapes, Stadiometer (39)                                                                     | 18-25 yrs       | Gender                | Overall                                                                  |
| <b>Coqueiro <i>et al.</i> (2009)</b>        | Brazil                 | Stratified sampling (1197 F, 708 M)              | Calipers and anthropometers (8)                                                                                                          | over 60 yrs     | Age, gender           | 60-64 yrs<br>65-69 yrs<br>70-74 yrs<br>75-80 yrs<br>>80 yrs              |
| <b>Cereda <i>et al.</i> (2010)</b>          | Italy                  | Stratified sampling (319 F, 326 M)               | A telescopic vertical steel stadiometer, a Harpenden anthropometer (4)                                                                   | 30-55 yrs       | Gender                | Overall                                                                  |
| <b>Chuan <i>et al.</i> (2010)</b>           | Indonesia<br>Singapore | Stratified sampling (241 F, 451 M)               | 1 Campbell caliper 20, 1 Campbell caliper 10, 1 segmometer, 1headboard, and 1 anthropometric measuring tape (37)                         | 18-45 yrs       | Gender,<br>region     | 18-45 yrs<br>18-45 yrs                                                   |

\* F= Females, M= Males

### 2.6.2. Studies for Population of Turkey

Until now, a number of studies performed about the anthropometry of population of Turkey. The first study is performed in 1937 by Public Statistics Directorate (DIE) and was called Anthropometric Survey of Turkey (Government Statistics Department). This study was conducted on 64000 individual adults spreading across 10 regions in 1937. In the study, the static anthropometric characteristics including body mass, stature, eye height, sitting height and arm span were collected (DIE, 1937).

Until 1980s there was no other anthropometric study worth to mention. In a study by Özok (1981) on 1000 industrial workers were measured with 50 dimensions. In this study, statistical data taken by simple random sampling method from Turkish employees shown with nine age groups with 5 years range were performed. This study includes some regression estimation equations for body dimensions.

Kayış and Özok (1991) used simple random sampling method to obtain 51 anthropometric measurements of 5109 army men between 18-26 years. In this study, they constructed some regression estimation equations for the body dimensions.

In another study, Kayış and Özok (1991) presented a study on 3584 children at their 6-13 years with 13 measurements. These statistical data were taken by simple random sampling method from eight different age groups from 6 to 13. Also, in this survey, they made some recommendations for design of school furniture.

In a survey by Gönen *et al.* (1991), the statistical data were obtained by simple random sampling method. 100 female ages 20-45 years from rural and urban areas were measured with 16 body dimensions.

Kaya *et al* (2003) studied the anthropometry of people living in Erzurum. In their study, 387 subjects aged 15 to 17 are measured for 18 dimensions. Then, “Adaptive Neuro-Fuzzy Inference System (ANFIS)” was used to estimate anthropometric measurements as an alternative to stepwise regression analysis. Six outputs (shoulder width, hip width, knee height, buttock-popliteal height, popliteal height, and height) were

selected for estimation purpose. The results showed that the number of inputs required estimating outputs varied with gender difference.

In a study by Yardımcı and Özçelik (2006), 15 dimensions of 650 housewives from Ankara were measured. They have found that 26.3 % of women were normal weight, 30.5 % overweight, and 38.9 % were obese, regarding their body mass index (BMI). Statistical results indicated that body mass index was affected the marital status, smoking habit, menopause, exercise, body stature and eating habit. Also, in this study, the relation between waist circumference and waist-hip ratio and age, BMI and number of children were found to be important.

In a study by Güleç *et al.* (2006), 1050 female and 1050 male subjects were measured with 20-65 years of age for 37 measurements. According to the results, the abdomen circumference of population of Turkey is larger than Europeans and Americans. The mean stature of women was 155.03 cm; the mean of their weights was 67.12 kg; while for the men they were 168.88 cm and 74.74 kg, respectively.

İşeri and Arslan (2009) estimated the body dimensions of population of Turkey by making a long distance survey, and they phoned the subjects to ask their age, stature and body weight. Then, they constructed some regression model for the anthropometric characteristics of the population of Turkey by using Pheasant's data related to 37 body dimensions. Their assumption was that there has been no difference in body measurements of population of Turkey for 45 years. Age is found a significant factor and it seems like Turkey is in the "secular trend" as most of the developing countries. Also the authors emphasize that Turkish population is fatter than most of the European counterparts. According to the Body Mass Index (BMI), 40% of the population was pre-obese while only 41% was in the normal range in 2009.

In a survey by Polat *et al.* (2010) 218 volunteer subjects at their 16 years of age were measured with 4 body dimensions. These subjects were soccer players and persons practicing fitness or sedentary. It was found that the highest humeral width value was achieved by the soccer group, where it was found to be no different from the fitness group and to be significantly higher than the sedentary group. When femur width parameter was

examined, it was determined that the soccer group was higher than the other two groups and that the fitness group was significantly higher than the sedentary group.

In the study by Karadağ *et al.* (2010) with 551 male subjects, gender and age effects were investigated. Linear regression analysis was carried out to derive predictive equations for the estimation of stature with adults (<50 years of age) according to the gender. This equation was then used to estimate height among elderly subjects. Of the cases, 60.3 % were <60 years (mean: 48.75); 39.7 % of the cases were >60 years (mean: 69.51). Estimated BMI (EBMI) measurements in the females and males >60 years were in average  $1.23 \text{ kg} / \text{m}^2$  and  $0.92 \text{ kg} / \text{m}^2$  higher than their real BMIs, respectively.

In summary, main findings related to the studies for the male population of Turkey can be listed as follows:

- In almost all studies, simple random sampling method is used in order to determine the distribution of the subjects. However, there was no detail no how this randomization was done. It seem studies included subjects in available and convenience.
- There was no study including all needed dimensions for various industries, and body measurements given in ISO standards were not taken into consideration.
- In all studies, traditional techniques were used to measure the subjects.
- There is a significant change in body mass and stature from 1980s to 2000s.
- Stature and body mass values were significantly affected by gender and age.
- The effect of job-groups on the anthropometric dimensions were not analysed in details.
- Some of the studies present regression equations of anthropometric measurements for the population of Turkey.

In Table 2.4, some studies given above are explained further in terms of sample types, equipment used and factors analyzed.

Table 2.4. Information of some studies about anthropometric measurements of Turkish subjects.

| Source                       | Sample type (n*)                     | Equipment (Number of Dimensions)                                            | Age range (yrs) | Independent factors   | Age-groups                                                                                                                                                                                                                                               |
|------------------------------|--------------------------------------|-----------------------------------------------------------------------------|-----------------|-----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Özok (1981)                  | Industrial workers (1000)            | Measurement platform designed by Özok <i>et al.</i> (50)                    | 16-60 yrs       | Age                   | 16-20 yrs (both genders)<br>21-25 yrs (both genders)<br>26-30 yrs (both genders)<br>31-35 yrs (both genders)<br>36-40 yrs (both genders)<br>41-45 yrs (both genders)<br>46-50 yrs (both genders)<br>51-55 yrs (both genders)<br>56-60 yrs (both genders) |
| Kayış and Özok (1991)        | Soldiers (5109 M)                    | A standard GPM anthropometer and an adjustable rigid right-angled seat (51) | 18-26 yrs       | Age                   | 18-26 yrs (both genders)                                                                                                                                                                                                                                 |
| Kayış and Özok (1991)        | Children (3584)                      | N/A (13)                                                                    | 6-13 yrs        | Region, social status | 6 yrs (both genders)<br>7 yrs (both genders)<br>8 yrs (both genders)<br>9 yrs (both genders)<br>10 yrs (both genders)<br>11 yrs (both genders)<br>12 yrs (both genders)<br>13 yrs (both genders)                                                         |
| Kaya <i>et al.</i> (2003)    | Teenagers (387)                      | A Harpenden anthropometer and a digital weighting scale (18)                | 15-17 yrs       | Gender                | 15 yrs<br>16 yrs<br>17 yrs                                                                                                                                                                                                                               |
| Güleç <i>et al.</i> (2006)   | Stratified sampling (1050 F, 1050 M) | Antropometer (36)                                                           | 20-65 yrs       | Age, region           | 20-65 yrs                                                                                                                                                                                                                                                |
| İşeri and Arslan (2009)      | Estimation                           | N/A (37)                                                                    | N/A             | Age, gender, region   | Overall                                                                                                                                                                                                                                                  |
| Karadağ <i>et al.</i> (2010) | Stratified sampling (551 M)          | A stadiometer, a fiberglass tape measure (3)                                | 19-97 yrs       | Gender, age           | <60 yrs<br>>60 yrs                                                                                                                                                                                                                                       |

\* F= Females, M= Males

### **3. RATIONALE AND OBJECTIVES OF THE STUDY**

#### **3.1. Rationale behind the Study**

In order to design workplaces, equipment, and products fit the capacities for reach, grasp, and clearance of most of the potential work force, anthropometric database is a common need for each of the nations (Pheasant, 2000). Using anthropometric data of a population to design for another may give rise to problems in daily use of equipment, materials, etc. Then, this may result in the lack of properly designed machines and equipment, which may reduce the work performance and increase the frequency of work-related injuries. For the anthropometric measurements of the population of Turkey, there are a number of studies. However, the data available are not complete in terms of needed dimensions, not up-to-date, and not representative of the population of Turkey to satisfy the needs of various industries, product design and clothing industry.

#### **3.2. Objectives of the Study**

Based on the rationale above, the objectives of this study are set for as follows:

- (i) generate an updated anthropometric database of adult male population of Turkey which is complete in terms of needed dimensions,
- (ii) investigate the effects of age and occupation on body dimensions,
- (iii) compare the developed anthropometric norms of the adult male population of Turkey with the population of several other countries and past data of population of Turkey,
- (iv) investigate the dimensional changes over time by comparing past data with the results of the present study.

## 4. METHODS

### 4.1. Phases of the Study

The phases of this study can be summarized by the following flow chart (Figure 4.1):

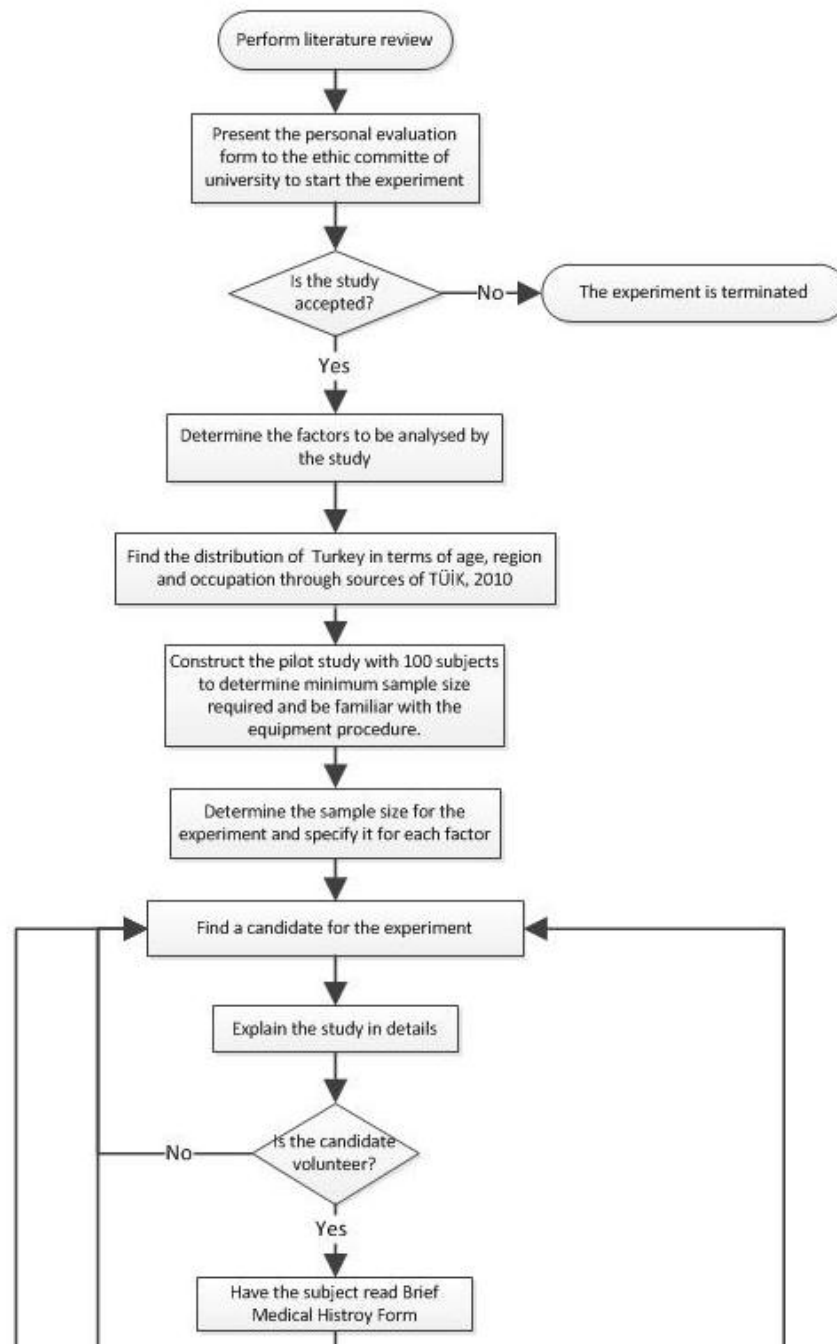


Figure 4.1. Flow chart for the study procedure.

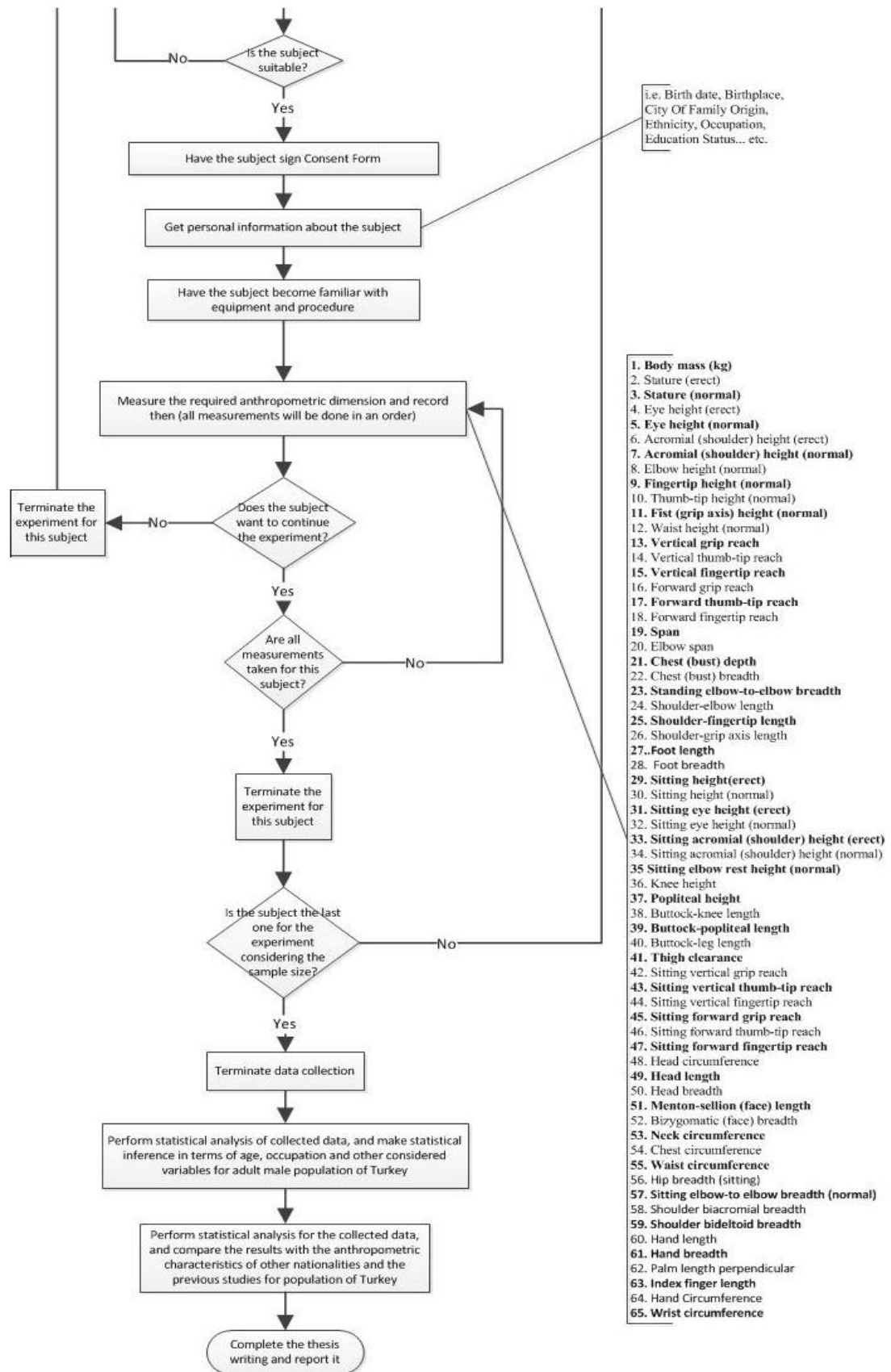


Figure 4.1. Flow chart for the study procedure (cont'd).

## 4.2. Measurements

In this study, 65 anthropometric measurements including those that are recommended in ISO standards and some additional ones are considered for this study. In selecting the anthropometric measurements need of various industries, such as workspace design, product design, clothing and architectural design, are considered. In Table 4.1, types of each body dimensions measured in this study are shown. In Table 4.2, these measurements are explained in details. In Figure 4.2, all anthropometric dimensions are shown together.

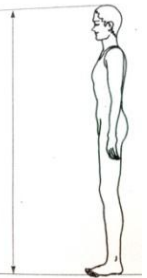
Table 4.1. Types of the anthropometric measurements.

| No | Anthropometric measurements         | Type    | No | Anthropometric measurements                 | Type    |
|----|-------------------------------------|---------|----|---------------------------------------------|---------|
| 1  | Body mass (kg)                      | Static  | 24 | Shoulder-elbow length                       | Static  |
| 2  | Stature (erect)                     | Static  | 25 | Shoulder-fingertip length                   | Static  |
| 3  | Stature (normal)                    | Static  | 26 | Shoulder-grip axis length                   | Static  |
| 4  | Eye height (erect)                  | Static  | 27 | Foot length                                 | Static  |
| 5  | Eye height (normal)                 | Static  | 28 | Foot breadth                                | Static  |
| 6  | Acromial (shoulder) height (erect)  | Static  | 29 | Sitting height(erect)                       | Static  |
| 7  | Acromial (shoulder) height (normal) | Static  | 30 | Sitting height (normal)                     | Static  |
| 8  | Elbow height (normal)               | Static  | 31 | Sitting eye height (erect)                  | Static  |
| 9  | Fingertip height (normal)           | Static  | 32 | Sitting eye height (normal)                 | Static  |
| 10 | Thumb-tip height (normal)           | Static  | 33 | Sitting acromial (shoulder) height (erect)  | Static  |
| 11 | Fist (grip axis) height (normal)    | Static  | 34 | Sitting acromial (shoulder) height (normal) | Static  |
| 12 | Waist height (normal)               | Static  | 35 | Sitting elbow rest height (normal)          | Static  |
| 13 | Vertical grip reach                 | Dynamic | 36 | Knee height                                 | Static  |
| 14 | Vertical thumb-tip reach            | Dynamic | 37 | Popliteal height                            | Static  |
| 15 | Vertical fingertip reach            | Dynamic | 38 | Buttock-knee length                         | Static  |
| 16 | Forward grip reach                  | Dynamic | 39 | Buttock-popliteal length                    | Static  |
| 17 | Forward thumb-tip reach             | Dynamic | 40 | Thigh clearance                             | Static  |
| 18 | Forward fingertip reach             | Dynamic | 41 | Buttock-leg length                          | Dynamic |
| 19 | Span                                | Dynamic | 42 | Sitting vertical grip reach                 | Dynamic |
| 20 | Elbow span                          | Dynamic | 43 | Sitting vertical thumb-tip reach            | Dynamic |
| 21 | Chest (bust) depth                  | Static  | 44 | Sitting vertical fingertip reach            | Dynamic |
| 22 | Chest (bust) breadth                | Static  | 45 | Sitting forward grip reach                  | Dynamic |
| 23 | Standing elbow-to-elbow breadth     | Static  | 46 | Sitting forward thumb-tip reach             | Dynamic |

Table 4.1. Types of the antropometric measurements (cont'd).

| No | Anthropometric measurements     | Type    | No | Anthropometric measurements             | Type   |
|----|---------------------------------|---------|----|-----------------------------------------|--------|
| 47 | Sitting forward fingertip reach | Dynamic | 57 | Sitting elbow-to elbow breadth (normal) | Static |
| 48 | Head circumference              | Static  | 58 | Shoulder biacromial breadth             | Static |
| 49 | Head length                     | Static  | 59 | Shoulder bideltoid breadth              | Static |
| 50 | Head breadth                    | Static  | 60 | Hand length                             | Static |
| 51 | Menton-sellion (face) length    | Static  | 61 | Hand breadth                            | Static |
| 52 | Bizygomatic (face) breadth      | Static  | 62 | Palm length perpendicular               | Static |
| 53 | Neck circumference              | Static  | 63 | Index finger length                     | Static |
| 54 | Chest circumference             | Static  | 64 | Hand Circumference                      | Static |
| 55 | Waist circumference             | Static  | 65 | Wrist circumference                     | Static |
| 56 | Hip breadth (sitting)           | Static  |    |                                         |        |

Table 4.2. Basic anthropometric measurements and their definitions (ISO 7250-1, 2008; Pheasant, 2000; Eastman Kodak Company, 1983; Lohman *et al.*, 1988; The National Academies Press, 2004; Peebles and Norris, 1998).

| Measure                                       | Definition                                                                                                                     | Measurement Details                                                                                                                                                                                                                                                  | Application Areas                                                                                                   | Equipment Required                              | Figure                                                                                |
|-----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|---------------------------------------------------------------------------------------|
| <b>1. Body weight (in kg)</b>                 | Total mass (weight) of the body.                                                                                               | Person wears minimal clothing. Shoes are off. Person stands on the middle of the scale with feet close and arms on the side close to the body. Person stands still, looking straight ahead.                                                                          | Used in the design of seated workplaces in which body mass is an important parameter.                               | Weighing scale                                  |    |
| <b>STANDING POSITIONS (in cm)</b>             |                                                                                                                                |                                                                                                                                                                                                                                                                      |                                                                                                                     |                                                 |                                                                                       |
| <b>2. Stature (erect)</b>                     | Vertical distance from the floor to the highest point of the head while standing erect, while holding the full breadth.        | Experimenter has to lower the headboard to the highest point of the head. Make sure the hair is compressed. Also, heels together with toes are pointing out about 60 degree angle and heels are touching on the base of the vertical back board of the stadiometer.* | Used for vertical clearances in workplaces or in locating equipment to avoid head collisions.                       | 1. The Harpenden Stadiometer<br>2. Grid Board** |   |
| <b>3. Stature (normal)</b>                    | Vertical distance from the floor to the highest point of the head while breathing normally.                                    |                                                                                                                                                                                                                                                                      |                                                                                                                     |                                                 |                                                                                       |
| <b>4. Acromial (shoulder) height (erect)</b>  | Vertical distance from the floor to the bony tip of the shoulder (acromion) while standing erect and holding the full breadth. | Subject stands with feet together, looking ahead. Shoulders are relaxed, with arms hanging freely.                                                                                                                                                                   | Used for maximum height location of controls or perform other assembly or packing tasks which cause muscle fatigue. | 1. The Harpenden Stadiometer<br>2. Grid Board   |  |
| <b>5. Acromial (shoulder) height (normal)</b> | Vertical distance from the floor to the bony tip of the shoulder (acromion) breathing normally.                                |                                                                                                                                                                                                                                                                      |                                                                                                                     |                                                 |                                                                                       |

\* : For all standing measurements, feet should be in this position.

\*\* : It was produced in Boğaziçi University Ergonomics Laboratory.

Table 4.2. Basic anthropometric measurements and their definitions (cont'd).

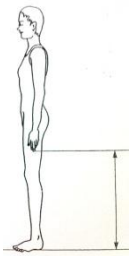
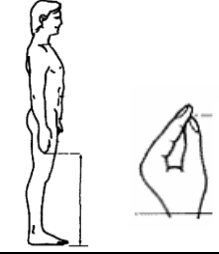
| STANDING POSITIONS (in cm)           |                                                                                                           |                                                                                                                                           |                                                                                                                                                    |                                               |                                                                                       |
|--------------------------------------|-----------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|---------------------------------------------------------------------------------------|
| Measure                              | Definition                                                                                                | Measurement Details                                                                                                                       | Application Areas                                                                                                                                  | Equipment Required                            | Figure                                                                                |
| <b>6. Eye height (erect)</b>         | Vertical distance from the floor to the outer corner of the eye while standing erect with full breathing. | Subject stands with feet together, looking ahead. Shoulders are relaxed, with arms hanging freely.                                        | Used for locating visual displays.                                                                                                                 | 1. The Harpenden Stadiometer<br>2. Grid Board |    |
| <b>7. Eye height (normal)</b>        | Vertical distance from the floor to the outer corner of eye, breathing normally.                          |                                                                                                                                           |                                                                                                                                                    |                                               |                                                                                       |
| <b>8. Elbow height (normal)</b>      | Vertical distance from the floor to the lowest bony tip point of the bent elbow, breathing normally.      | Subject stands relaxed with feet together, looking ahead. Upper arm hangs freely downwards, with forearm flexed at 90 degree angle to it. | Used for workplace place in which it is important for objects not to have to bend at the waist or hips, reducing the potential for muscle fatigue. | 1. The Harpenden Stadiometer<br>2. Grid Board |    |
| <b>9. Fingertip height (normal)</b>  | Vertical distance from the floor to the tip of the middle finger, breathing normally.                     | Subject stands relaxed with feet together, looking ahead, hand and finger held straight down beside the body.                             | Used for workplace place in which it is important for objects to be handled or control operated without having to bend the knees.                  | 1. The Harpenden Stadiometer<br>2. Grid Board |   |
| <b>10. Thumb-tip height (normal)</b> | Vertical distance from the floor to the thumb-tip, breathing normally.                                    | Subject stands relaxed with feet together, looking ahead, the fingers closes to each others as seen in the figure.                        |                                                                                                                                                    | 1. The Harpenden Stadiometer<br>2. Grid Board |  |

Table 4.2. Basic anthropometric measurements and their definitions (cont'd).

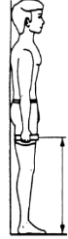
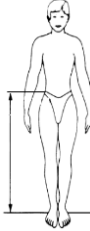
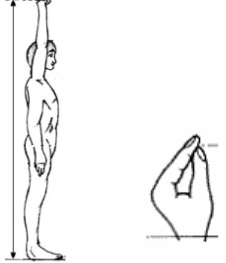
| STANDING POSITIONS (in cm)                                   |                                                                                                                                                                                |                                                                                                  |                                                                                                                                   |                                                                     |                                                                                       |
|--------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Measure                                                      | Definition                                                                                                                                                                     | Measurement Details                                                                              | Application Areas                                                                                                                 | Equipment Required                                                  | Figure                                                                                |
| <b>11. Fist (grip axis) height (knuckle height) (normal)</b> | Vertical distance from the floor to the grip axis of the fist. In order words, it is vertical distance from the floor to the knuckle of the middle finger, breathing normally. | Subject stands relaxed with feet together, looking ahead, the arms hanging straight at the side. | Used for workplace place in which it is important for objects to be handled or control operated without having to bend the knees. | 1. The Harpenden Stadiometer<br>2. Grid Board<br>3. Handle Diameter |    |
| <b>12. Waist height (normal)</b>                             | Vertical distance from the floor to the anterosuperior iliac spine (the most downward-directed point of the iliac crest), breathing normally.                                  | Subject stands relaxed with feet together, looking ahead.                                        | Used for workplace place in which it is important for objects to be handled below waist level.                                    | 1. The Harpenden Stadiometer<br>2. Grid Board                       |    |
| <b>13. Vertical grip reach</b>                               | Vertical distance from a vertical surface to the grip axis of the hand while the subject is standing and holding cylinder can handle with a diameter of 3.55 cm.               | Subject stands erect, weight evenly balanced, with the arm extended vertically above the head.   | Used for defining how high an overhead control can be.                                                                            | 1. The Harpenden Stadiometer<br>2. Grid Board<br>3. Handle Diameter |   |
| <b>14. Vertical thumb-tip reach</b>                          | Vertical distance from the floor to the thumb-tip vertically while the subject is standing.                                                                                    | Subject stands erect, weight evenly balanced, with the arm extended vertically above the head.   |                                                                                                                                   | 1. The Harpenden Stadiometer<br>2. Grid Board                       |  |

Table 4.2. Basic anthropometric measurements and their definitions (cont'd).

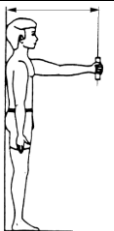
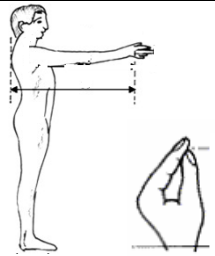
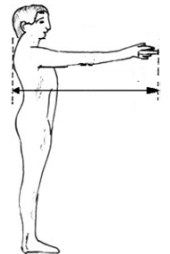
| STANDING POSITIONS (in cm)          |                                                                                                                                                                                                    |                                                                                                                                   |                                                                                                                                                 |                                                                     |                                                                                       |
|-------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Measure                             | Definition                                                                                                                                                                                         | Measurement Details                                                                                                               | Application Areas                                                                                                                               | Equipment Required                                                  | Figure                                                                                |
| <b>15. Vertical fingertip reach</b> | Vertical distance from the floor to the tip of the middle finger while the subject is standing and reaching.                                                                                       | Subject stands erect, weight evenly balanced, with the arm extended vertically above the head and hand and fingers held straight. | Used for defining how high an overhead control can be.                                                                                          | 1. The Harpenden Stadiometer<br>2. Grid Board                       |    |
| <b>16. Forward grip reach</b>       | Horizontal distance from a vertical surface to the grip axis of the hand while the subject leans both shoulder blades against the vertical surface.                                                | Subject stands erect, the arm and hand stretched horizontally in front of them. Subjects hold a cylinder diameter of 3.55 cm.     | Used for defining how far forward from a fixed structure, such as a wall, a person who is strained from leaning forward can reach for controls. | 1. The Harpenden Stadiometer<br>2. Grid Board<br>3. Handle Diameter |    |
| <b>17. Forward thumb-tip reach</b>  | Horizontal distance from a vertical surface to the middle of the pad of the thumb where contact is made in a pinch-grip while the subject leans both shoulder blades against the vertical surface. | Subject stands erect, the arm and hand stretched horizontally in front of them.                                                   |                                                                                                                                                 | Grid Board                                                          |   |
| <b>18. Forward fingertip reach</b>  | Horizontal distance between back of the shoulders to the tip of the middle finger while the subject is standing.                                                                                   | Subject stands erect, the arm and hand stretched horizontally in front of them.                                                   |                                                                                                                                                 | Grid Board                                                          |  |

Table 4.2. Basic anthropometric measurements and their definitions (cont'd).

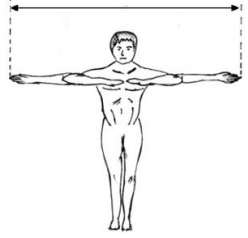
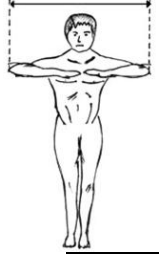
| STANDING POSITIONS (in cm)      |                                                                                                                                                                             |                                                                                                                                                                      |                                                                                           |                     |                                                                                       |
|---------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|---------------------|---------------------------------------------------------------------------------------|
| Measure                         | Definition                                                                                                                                                                  | Measurement Details                                                                                                                                                  | Application Areas                                                                         | Equipment Required  | Figure                                                                                |
| <b>19. Span</b>                 | The maximum horizontal distance between the tips of the middle fingers when both arms are stretched out sideways.                                                           | Subject stands erect, feet together and the arms outstretched on other side in line with the shoulders.                                                              | Used for defining the maximum reach through two arms in the design of workplaces.         | Grid Board          |    |
| <b>20. Elbow span</b>           | The horizontal distance between the tips of the elbows when both upper limbs are stretched out sideways and the elbows are fully flexed so that the fingertips touch chest. | Subject stands with the upper arms spread horizontally on each side of the body and the elbows are flexed to bring the hands in to touch the chest.                  | Used for defining the horizontal distance between two elbows in the design of workplaces. | Grid Board          |    |
| <b>21. Chest (bust) depth</b>   | Horizontal depth of the torso measured in the midsagittal plane at mesosternal level.                                                                                       | Subject stands fully erect with feet together. Arms hang freely downwards. The measure is taken at the end of quietly breathing out, without compressing the breast. | Used for defining the horizontal depth of torso in the design of workplaces.              | Large Anthropometer |   |
| <b>22. Chest (bust) breadth</b> | Horizontal breadth of the torso measured at the chest at the level of the nipples.                                                                                          | Subject stands erect, arms held slightly away from the sides, breathing quietly.                                                                                     | Used for defining the horizontal breadth of torso in the design of workplaces.            | Large Anthropometer |  |

Table 4.2. Basic anthropometric measurements and their definitions (cont'd).

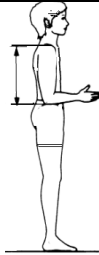
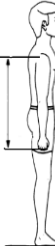
| STANDING POSITIONS (in cm)                 |                                                                                                 |                                                                                                          |                                                                                       |                                              |                                                                                       |
|--------------------------------------------|-------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|----------------------------------------------|---------------------------------------------------------------------------------------|
| Measure                                    | Definition                                                                                      | Measurement Details                                                                                      | Application Areas                                                                     | Equipment Required                           | Figure                                                                                |
| <b>23. Standing elbow-to-elbow breadth</b> | Horizontal distance between the outer borders of the elbows.                                    | Subject stands with the elbows flexed to the 90 degrees, the upper arms hanging vertically at the sides. | Used for defining the horizontal distance between elbows in the design of workplaces. | Large Anthropometer                          |    |
| <b>24. Shoulder-elbow length</b>           | Vertical distance from the bony tip of the shoulder (acromion) to the underside of the elbow.   | Subject stands, with the upper arm vertical and the elbow flexed to 90 degrees.                          | Used for defining the level at which shoulder abduction.                              | Large Anthropometer                          |    |
| <b>25. Shoulder-fingertip length</b>       | Vertical distance from the bony tip of the shoulder (acromion) to the tip of the middle finger. | Subject stands, with the upper arm vertical flexed 180 degrees.                                          | Used for defining the level at which the person can reach and control an equipment.   | Large Anthropometer                          |   |
| <b>26. Shoulder-grip axis length</b>       | Vertical distance from the bony tip of the shoulder (acromion) to the grip axis.                | Subject stands, with the upper arm vertical flexed 180 degrees.                                          |                                                                                       | 1. Large Anthropometer<br>2. Handle Diameter |  |

Table 4.2. Basic anthropometric measurements and their definitions (cont'd).

| SEATED POSITIONS (in cm)                               |                                                                                                                                                                                                          |                                                                            |                                                                    |                                                        |                                                                                       |
|--------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|--------------------------------------------------------------------|--------------------------------------------------------|---------------------------------------------------------------------------------------|
| Measure                                                | Definition                                                                                                                                                                                               | Measurement Details                                                        | Application Areas                                                  | Equipment Required                                     | Figure                                                                                |
| 27. <b>Sitting height (erect)</b>                      | Vertical distance from a horizontal sitting surface to the highest point of the head while sitting erect, breathing fully.                                                                               | Subject sits, looking straight ahead, the elbows are flexed at 90 degrees. | Used for defining the vertical clearance needed for seated work.   | The Harpenden Sitting Height Table                     |    |
| 28. <b>Sitting height (normal)</b>                     | Vertical distance from a horizontal sitting surface to the highest point of the head, breathing normally.                                                                                                |                                                                            |                                                                    |                                                        |                                                                                       |
| 29. <b>Sitting acromial (shoulder) height (erect)</b>  | Vertical distance from a horizontal sitting surface to the bony tip of the shoulder (acromion), sitting erect.                                                                                           | Subject sits, looking straight ahead, the elbows are flexed at 90 degrees. | Used for defining the top of the torso for chair design.           | 1. The Harpenden Sitting Height Table<br>2. Grid Board |    |
| 30. <b>Sitting acromial (shoulder) height (normal)</b> | Vertical distance from a horizontal sitting surface to the bony tip of the shoulder, breathing normally.                                                                                                 |                                                                            |                                                                    |                                                        |                                                                                       |
| 31. <b>Sitting eye height (erect)</b>                  | Vertical distance from a horizontal sitting surface to the outer corner of the eye, sitting erect, breathing fully.                                                                                      | Subject sits, looking straight ahead, the elbows are flexed at 90 degrees. | Used to define locations for visual displays in seated workplaces. | 1. The Harpenden Sitting Height Table<br>2. Grid Board |   |
| 32. <b>Sitting eye height (normal)</b>                 | Vertical distance from a horizontal sitting surface to the outer corner of the eye, breathing normally.                                                                                                  |                                                                            |                                                                    |                                                        |                                                                                       |
| 33. <b>Sitting elbow rest height (normal)</b>          | Vertical distance from a horizontal sitting surface to the lowest bony point of the elbow bent at a right angle with the forearm horizontal, breathing normally and elbows are not touching to the body. | Subject sits, looking straight ahead, the elbows are flexed at 90 degrees. | Used for design of seated workplace height.                        | Large Anthropometer                                    |  |

Table 4.2. Basic anthropometric measurements and their definitions (cont'd).

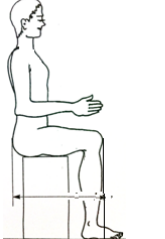
| SEATED POSITIONS (in cm)            |                                                                                                                                   |                                                                                                                                                                                                   |                                                                                                                  |                                                               |                                                                                       |
|-------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Measure                             | Definition                                                                                                                        | Measurement Details                                                                                                                                                                               | Application Areas                                                                                                | Equipment Required                                            | Figure                                                                                |
| <b>34. Knee height</b>              | Vertical distance from the floor to the highest tip of the bony of knee.                                                          | Subject sits, looking straight ahead, the elbows are flexed at 90 degrees. The seat should be adjusted so that the subject can sit with the lower legs vertical, thighs horizontal and feet flat. | Used in the design of seated workplace heights.                                                                  | 1.The Harpenden Sitting Height Table<br>2.Large Anthropometer |    |
| <b>35. Popliteal height</b>         | Vertical distance from the foot-rest surface to the lower surface of the thigh immediately behind the knee, bent at right angles. | Subject sits, looking straight ahead, the elbows are flexed at 90 degrees. The seat should be adjusted so that the subject can sit with the lower legs vertical, thighs horizontal and feet flat. | Used for defining seat height adjustability and footrest needs for seated workplaces.                            | 1.The Harpenden Sitting Height Table<br>2.Large Anthropometer |    |
| <b>36. Buttock-knee length</b>      | Horizontal distance from the foremost point of the knee-cap to the rearmost point of the buttock.                                 | Subject sits, looking straight ahead, the elbows are flexed at 90 degrees. The seat should be adjusted so that the subject can sit with the lower legs vertical, thighs horizontal and feet flat. | Used for defining seat depth for chairs and minimum forward clearance for seated workplaces.                     | 1.The Harpenden Sitting Height Table<br>2.Large Anthropometer |   |
| <b>37. Buttock-popliteal length</b> | Horizontal distance from the back point of the knee-cap to the rearmost point of the buttock.                                     | Subject sits, looking straight ahead, the elbows are flexed at 90 degrees. The seat should be adjusted so that the subject can sit with the lower legs vertical, thighs horizontal and feet flat. | Used for defining seat depth for a chair to ensure that pressure on the underside of the thigh is not excessive. | 1.The Harpenden Sitting Height Table<br>2.Large Anthropometer |  |

Table 4.2. Basic anthropometric measurements and their definitions (cont'd).

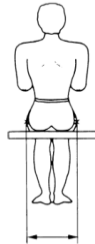
| SEATED POSITIONS (in cm)                           |                                                                                                                                                              |                                                                                                                                                                                                   |                                                                                                                                                 |                                                               |                                                                                       |
|----------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Measure                                            | Definition                                                                                                                                                   | Measurement Details                                                                                                                                                                               | Application Areas                                                                                                                               | Equipment Required                                            | Figure                                                                                |
| <b>38. Buttock-Leg Length</b>                      | Horizontal distance from the most posterior part of the buttock to the sole of the foot.                                                                     | Subject sits, looking straight ahead, the elbows are flexed at 90 degrees. The subject sits erect with one leg extended horizontally in front of them.                                            | Used for defining maximum leg clearance for seated workplaces and for maintenance tasks where the person has to sit on the floor to do the task | 1.The Harpenden Sitting Height Table<br>2.Measuring tape      |    |
| <b>39. Thigh clearance</b>                         | Vertical distance from the sitting surface to the upper, uncompressed, surface of the thigh where the thigh depth is greatest.                               | Subject sits, looking straight ahead, the elbows are flexed at 90 degrees. The seat should be adjusted so that the subject can sit with the lower legs vertical, thighs horizontal and feet flat. | Used in the design of seated work surface heights or in the selection of the adjustability levels of a chair.                                   | 1.The Harpenden Sitting Height Table<br>2.Large Anthropometer |    |
| <b>40. Hip breadth (sitting)</b>                   | Horizontal breadth of the body measured across the widest portion of the hips.                                                                               | Subject sits erect and with the legs and feet together.                                                                                                                                           | Used for defining seat widths and whole-body access port clearance.                                                                             | 1.The Harpenden Sitting Height Table<br>2.Large Anthropometer |   |
| <b>41. Sitting elbow-to elbow breadth (normal)</b> | Maximum horizontal distance between the lateral surfaces of the elbow region, breathing normally. Upper arms are making about 15 degree angle with the body. | Subject stands with the elbows flexed to the 90 degrees, the upper arms hanging vertically at the sides.                                                                                          | Used for defining the horizontal distance between elbows in the design of workplaces.                                                           | 1.The Harpenden Sitting Height Table<br>2.Large Anthropometer |  |

Table 4.2. Basic anthropometric measurements and their definitions (cont'd).

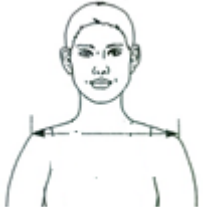
| SEATED POSITIONS (in cm)                    |                                                                                                                                                |                                                                                               |                                                                                              |                                                                              |                                                                                       |
|---------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Measure                                     | Definition                                                                                                                                     | Measurement Details                                                                           | Application Areas                                                                            | Equipment Required                                                           | Figure                                                                                |
| <b>42. Shoulder biacromial breadth</b>      | Horizontal distance along a straight line from the bony tips of shoulders (acromion).                                                          | Subject sits erect with the arms flexed at 90 degrees, measuring from the behind the subject. | Used for defining whole-body clearance requirements for access ports.                        | 1. The Harpenden Sitting Height Table<br>2. Large Anthropometer              |    |
| <b>43. Shoulder bideltoid breadth</b>       | Horizontal distance across the maximum lateral protrusions of the right and left deltoid muscles.                                              | Subject sits erect with the arms flexed at 90 degrees, measuring from the behind the subject. |                                                                                              | 1. The Harpenden Sitting Height Table<br>2. Large Anthropometer              |    |
| <b>44. Sitting vertical grip reach</b>      | Vertical distance from a vertical sitting surface to the grip axis of the hand while the subject is sitting, holding cylinder handle diameter. | Subject sits erect, weight evenly balanced, with the arm extended vertically above the head.  | Used for defining the maximum height at which controls should be located in overhead panels. | 1. The Harpenden Sitting Height Table<br>2. Grid Board<br>3. Handle Diameter |   |
| <b>45. Sitting vertical thumb-tip reach</b> | Vertical distance from a vertical sitting surface to the thumb-tip while the subject is sitting                                                | Subject sits erect, weight evenly balanced, with the arm extended vertically above the head.  |                                                                                              | 1. The Harpenden Sitting Height Table<br>2. Grid Board                       |  |

Table 4.2. Basic anthropometric measurements and their definitions (cont'd).

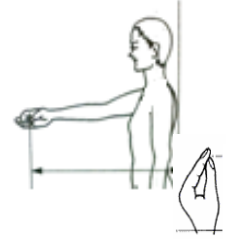
| SEATED POSITIONS (in cm)                    |                                                                                                                             |                                                                                                                                 |                                                                                                                                                               |                                                                              |                                                                                       |
|---------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Measure                                     | Definition                                                                                                                  | Measurement Details                                                                                                             | Application Areas                                                                                                                                             | Equipment Required                                                           | Figure                                                                                |
| <b>46. Sitting vertical fingertip reach</b> | Vertical distance from a vertical sitting surface to the tip of the middle finger of the hand while the subject is sitting. | Subject sits erect, weight evenly balanced, with the arm extended vertically above the head and hand and fingers held straight. | Used for defining the maximum height at which controls should be located in overhead panels.                                                                  | 1. The Harpenden Sitting Height Table<br>2. Grid Board                       |    |
| <b>47. Sitting forward grip reach</b>       | Horizontal distance from the wall to the grip reach while the subject is sitting, holding cylinder handle diameter.         | Subject sits erect, the arm and hand stretched horizontally in front of them.                                                   | Used for defining how far forward from a fixed structure, such as a wall, a person who is strained from leaning forward can reach for controls while sitting. | 1. The Harpenden Sitting Height Table<br>2. Grid Board<br>3. Handle Diameter |    |
| <b>48. Sitting forward thumb-tip reach</b>  | Horizontal distance from the wall to the thumb-tip reach while the subject is sitting                                       | Subject sits erect, the arm and hand stretched horizontally in front of them.                                                   |                                                                                                                                                               | 1. The Harpenden Sitting Height Table<br>2. Grid Board                       |   |
| <b>49. Sitting forward fingertip reach</b>  | Horizontal distance from the wall to the tip of the middle finger reach while the subject is sitting.                       | Subject sits erect, the arm and hand stretched horizontally in front of them.                                                   |                                                                                                                                                               | 1. The Harpenden Sitting Height Table<br>2. Grid Board                       |  |

Table 4.2. Basic anthropometric measurements and their definitions (cont'd).

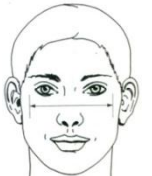
| HEAD MEASUREMENTS (in cm)               |                                                                                                                                                             |                                                                      |                                                                                  |                     |                                                                                       |
|-----------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------|----------------------------------------------------------------------------------|---------------------|---------------------------------------------------------------------------------------|
| Measure                                 | Definition                                                                                                                                                  | Measurement Details                                                  | Application Areas                                                                | Equipment Required  | Figure                                                                                |
| <b>50. Head circumference</b>           | Maximum, approximately horizontal, circumference of head measured just above the eyebrows at the front and the most protruding portion of the back of head. | Subject sits, looking straight ahead, and hair should be compressed. | Used in head protective equipment design, such as helmets.                       | Measuring tape      |    |
| <b>51. Head length</b>                  | Horizontal distance along a straight line between the glabella (brow bridges) and the most protruding portion of the back of the head.                      | Subject sits, looking straight ahead, and hair should be compressed. |                                                                                  | Small Anthropometer |    |
| <b>52. Head breadth</b>                 | The maximum horizontal breadth of head above and behind the ears, where the head is broadest.                                                               | Subject sits, looking straight ahead, and hair should be compressed. | Used in the design of clothing and of protective equipment, such as respirators. | Small Anthropometer |    |
| <b>53. Menton-sellion (face) length</b> | Vertical distance from the bony tip of the chin to the depression (sellion) at the top of the nose, below the brow ridge.                                   | Subject sits, looking straight ahead.                                | Used in design of protective equipment, such as masks.                           | Kumpas or Caliper   |   |
| <b>54. Bizygomatic (face) breadth</b>   | The maximum horizontal breadth of the face between the broadest portions of the cheekbones, between the eyes and the ears.                                  | Subject sits, looking straight ahead.                                | Used in eye protective equipment design, such as goggles.                        | Kumpas or Caliper   |  |

Table 4.2. Basic anthropometric measurements and their definitions (cont'd).

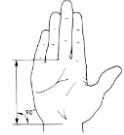
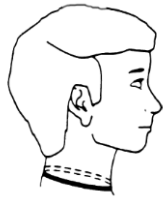
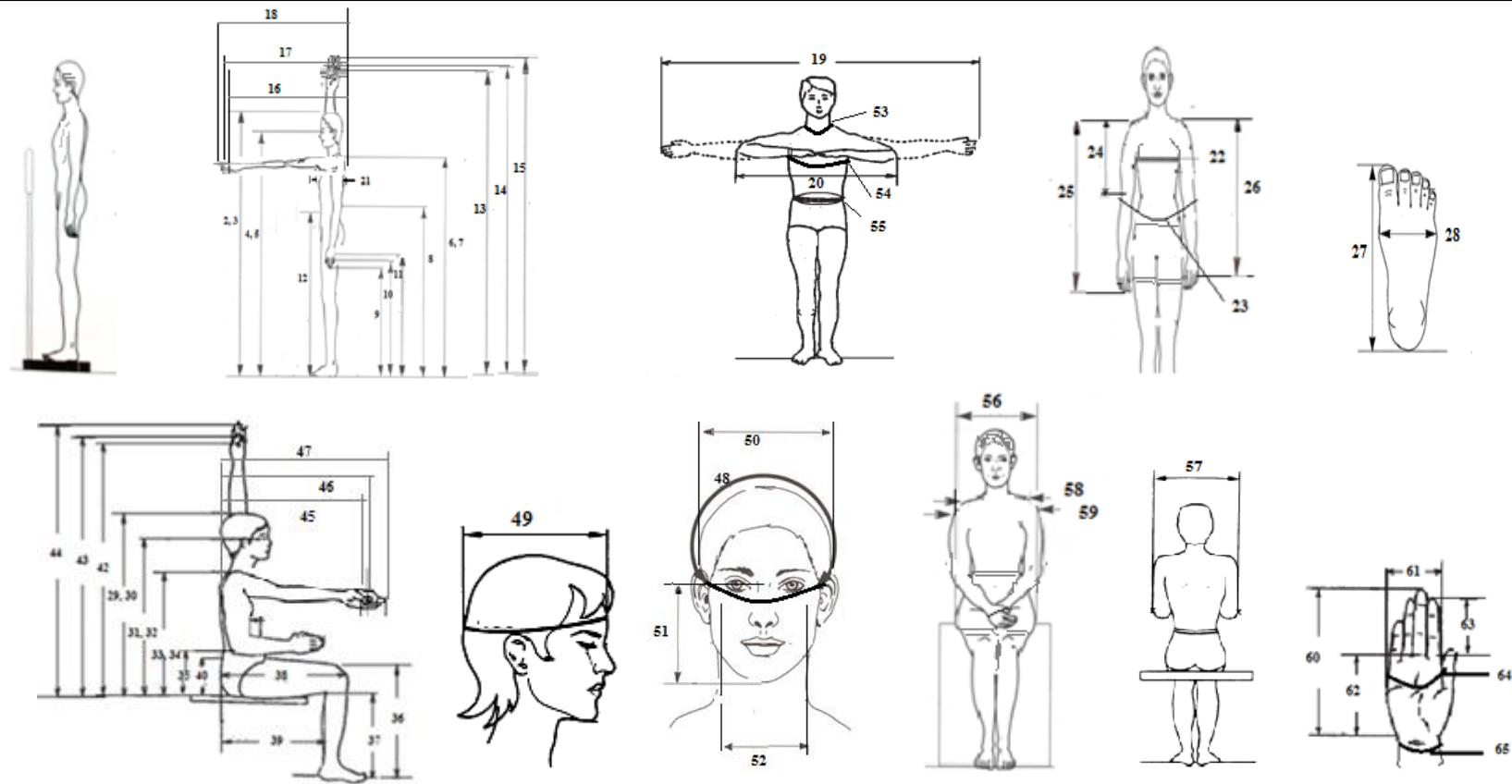
| HAND MEASUREMENTS (in cm)     |                                                                                                                                    |                                                                                                                                |                                                                                             |                    |                                                                                       |
|-------------------------------|------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|--------------------|---------------------------------------------------------------------------------------|
| Measure                       | Definition                                                                                                                         | Measurement Details                                                                                                            | Application Areas                                                                           | Equipment Required | Figure                                                                                |
| 55. Hand length               | Perpendicular distance from a line drawn between the styloid processes to the tip of the middle finger.                            | Subject sits, and the hand and fingers should be held straight and flat, palm uppermost.                                       | Used to define the working space of the hand in maintenance tasks and for hand tool design. | Kumpas or Caliper  |    |
| 56. Hand breadth              | Distance across the palm of the hand at the junction between the palm and the fingers, not including the thumb.                    | Subject sits, and the hand and fingers should be held straight and flat, palm uppermost.                                       | Used to define clearances for the working hand and handle dimensions of tools.              | Kumpas or Caliper  |    |
| 57. Palm length perpendicular | Distance from the wrist crease to the crease at the base of the middle finger.                                                     | Subject sits, and the hand and fingers should be held straight and flat.                                                       | Used for hand tool design.                                                                  | Kumpas or Caliper  |    |
| 58. Index finger length       | Distance from the tip of the index finger to the base of the finger at the level of the skin web between it and the middle finger. | Subject sits, and the hand and fingers should be held straight and flat, palm uppermost.                                       | Used to define the maximum depths of control buttons set inside equipment.                  | Kumpas or Caliper  |   |
| 59. Hand Circumference        | The circumference of the hand, measured around the palm at the junction between the palm and the fingers.                          | Subject sits, and the hand and fingers should be held straight and flat.                                                       | Used for hand tool design.                                                                  | Measuring tape     |  |
| 60. Wrist circumference       | Circumference of wrist at the level of the wrist crease.                                                                           | Subject sits, and the hand and fingers should be held straight and flat. This is a minimum measurement of wrist circumference. | Used for hand tool design.                                                                  | Measuring tape     |  |

Table 4.2. Basic anthropometric measurements and their definitions (cont'd).

| FOOT MEASUREMENTS (in cm) |                                                                                                               |                                                                |                                                                                                               |                                      |                                                                                     |
|---------------------------|---------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|--------------------------------------|-------------------------------------------------------------------------------------|
| Measure                   | Definition                                                                                                    | Measurement Details                                            | Application Areas                                                                                             | Equipment Required                   | Figure                                                                              |
| <b>61. Foot length</b>    | The maximum horizontal distance from the tip of the longest toe to the back of the heel.                      | Subject stands with their weight evenly balanced on both feet. | Used to define foot pedal dimensions and foot clearance at standing workplaces or around production machines. | Small Anthropometer                  |  |
| <b>62. Foot breadth</b>   | The maximum horizontal distance across the widest point of the foot, perpendicular to the length of the foot. | Subject stands with their weight evenly balanced on both feet. | Used to define foot pedal dimensions and horizontal clearance at standing workplaces.                         | 1. Small Anthropometer<br>2. Caliper |  |

Table 4.2. Basic anthropometric measurements and their definitions (cont'd).

| OTHER CIRCUMFERENCES (in cm)   |                                                                                                                    |                                                                                       |                                                            |                    |                                                                                      |
|--------------------------------|--------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|------------------------------------------------------------|--------------------|--------------------------------------------------------------------------------------|
| Measure                        | Definition                                                                                                         | Measurement Details                                                                   | Application Areas                                          | Equipment Required | Figure                                                                               |
| <b>63. Neck circumference</b>  | Circumference around the neck, halfway between the Adam's apple and the top of the breastbone.                     | Subject should stand; and pressure on the tape should be minimal to avoid discomfort. | Used in design of clothing and neck protective equipments. | Measuring tape     |   |
| <b>64. Chest circumference</b> | Maximum circumference, measured horizontally around the chest at the level of the nipples.                         | Subject stands erect, looking forwards, with shoulders relaxed and breathing quietly. | Used in design of clothing.                                | Measuring tape     |   |
| <b>65. Waist circumference</b> | Circumference measured horizontally at the level of the wrist (where the smallest abdominal circumference occurs). | Subject stands erect with the arms held slightly away from the sides of the body.     | Used in design of clothing.                                | Measuring tape     |  |



1: Body Mass, 2: Stature (erect), 3: Stature (normal), 4: Eye height (erect), 5: Eye height (normal), 6: Acromial (shoulder) height (erect), 7: Acromial (shoulder) height (normal), 8: Elbow height (normal), 9: Fingertip height (normal), 10: Thumb-tip height (normal), 11: Fist (grip axis) height (normal), 12: Waist height (normal), 13: Vertical grip reach, 14: Vertical thumb-tip reach, 15: Vertical fingertip reach, 16: Forward grip reach, 17: Forward thumb-tip reach, 18: Forward fingertip reach, 19: Span, 20: Elbow span, 21: Chest (bust) depth, 22: Chest (bust) breadth, 23: Standing elbow-to-elbow breadth, 24: Shoulder-elbow length, 25: Shoulder-fingertip length, 26: Shoulder-grip axis length, 27: Foot length, 28: Foot breadth, 29: Sitting height(erect), 30: Sitting height (normal), 31: Sitting eye height (erect), 32: Sitting eye height (normal), 33: Sitting acromial (shoulder) height (erect), 34: Sitting acromial (shoulder) height (normal), 35: Sitting elbow rest height (normal), 36: Knee height, 37: Popliteal height, 38: Buttock-knee length, 39: Buttock-popliteal length, 40: Thigh clearance, 41: Buttock-leg length, 42: Sitting vertical grip reach, 43: Sitting vertical thumb-tip reach, 44: Sitting vertical fingertip reach, 45: Sitting forward grip reach, 46: Sitting forward thumb-tip reach, 47: Sitting forward fingertip reach, 48: Head circumference, 49: Head length, 50: Head breadth, 51: Menton-sellion (face) length, 52: Bizygomatic (face) breadth, 53: Neck circumference, 54: Chest circumference, 55: Waist circumference, 56: Hip breadth (sitting), 57: Sitting elbow-to elbow breadth (normal), 58: Shoulder biacromial breadth, 59: Shoulder bideltoid breadth, 60: Hand length, 61: Hand breadth, 62: Palm length perpendicular, 63: Index finger length, 64: Hand circumference, 65: Wrist circumference.

Figure 4.2. Basic anthropometric measurements used in this study.

### 4.3. Equipment

Standard tools for anthropometric measurement, used for body mass, lengths, breadths and circumferences are given as following;

#### 4.3.1. Holtain Harpenden Stadiometer

The structure of the Harpenden Stadiometer, which is made of light alloy angle, can be moved easily. There is a wooden piece on it, and it is provided with adjustable wall brackets for mounting purposes. Therefore, it can be moved up and down in a quick way. The stadiometer head-block operates via miniature ball-bearing rollers in order to ensure a movement which is free yet without cross-play. Then, most of standing measurements can be taken through a high speed Veeder-Root counter on this stadiometer. It counts approximately 1500 mm length. By this context, in order to measure all standing vertical reach positions for each subject the stadiometer was placed up to 900 mm from the floor. So a wooden piece was added to the below part of stadiometer. It was stated on the wall for providing precise solutions. Figure 4.3 shows this equipment.



Figure 4.3. Holtain Harpenden Stadiometer.

#### 4.3.2. Holtain Harpenden Sitting Height Table

Holtain Harpenden Sitting Height Table is preferred in anthropometric studies to measure seated postures. There is a wooden piece on the back part of this table, and it can

be moved up and down in a quick way. By this way, it gives accurate and direct readings from 320 mm to 1090 mm. Then, most of sitting measurements can be taken through a counter-balanced head block. In addition it has a secondary carriage, fitted with an anti-reverse carriage lock, in order to compensate for upper leg variations: and an adjustable foot-rest in order to compensate for the lower leg variations. On the other hand, this measuring table was placed next to the wall for providing precise solutions. Figure 4.4 shows this equipment.



Figure 4.4. Holtain Harpenden Sitting Height Table.

#### 4.3.3. Grid Board

An orthogonal two-piece gridlined board was produced at Boğaziçi University Ergonomics Laboratory to be used in anthropometric studies as can be seen in Figure 4.5. Two wooden pieces about 130 mm x 250 mm and 260 mm x 250 mm were placed 90 degree angle with each others. All of its dimensions were determined according to 99 % of population of Turkey given in the previous studies. The aim of using this equipment is to measure almost all vertical dimensions and also horizontal reach positions in a precise way; in addition, it was used to check the values of stature and eye height were measured by the stadiometer.



Figure 4.5. Grid Board.

#### 4.3.4. Weighing Scale

Weighting scale is a measuring instrument for determining the weight of an object. A spring scale measures weight by the distance a spring deflects under its load. A balance compares the unknown weight to a standard weight using a horizontal lever. It is used in the laboratory study to determine the weights of the subjects. Figure 4.6 shows the scale used in this study.



Figure 4.6. Weighing scale.

#### 4.3.5. Anthropometers

The large anthropometer has a range of 0 to 600mm in 0.1 cm increments while the small one has a range of 0 to 300 mm. Popular uses include measuring shoulder width, long bone length and chest depth for tracking growth. Aluminum in construction, it uses a

spring-loaded ball bearing in a sliding C-shaped arm to provide accurate and precise measurement. Large and small anthropometers are illustrated in Figure 4.7.



Figure 4.7. Large and small anthropometers.

#### 4.3.6. Caliper

Calipers were used to measure the distance between two opposing sides of the subjects including length and breadth measurements. There is an important point that the edges of the caliper have to be adjusted to fit across the points to be measured. Then, the caliper was removed, and the distance was read through the scales on the caliper. The caliper used in this study is designed to measure the external size of an object. There is a high degree of accuracy and repeatability about reading the result on this equipment in shown in Figure 4.8.



Figure 4.8. Caliper.

#### 4.3.7. Measuring Tapes

In this study, two types of tape measures were used as other ergonomic measurement instruments. Both of them have two sides where you can read the data. The tape measures

used for large dimensions of the subject have a length of 3000 mm. Figure 4.9 shows the measuring tapes used in the laboratory in this study.



Figure 4.9. Measuring tapes.

#### 4.3.8. Cylindrical Handle

In this study, a wooden cylinder handle with about 3.55 cm diameter was used as another ergonomic measurement instrument. It was useful for grip reach measurements of subjects. Kong and Lowe (2005) indicate that the optimal handle diameter was 19.7% of the user's hand length. Then, to evaluate grip anthropometric measurements, handle diameter was designed on 3.55 cm in diameter as can be seen Figure 4.10.



Figure 4.10. Handle diameter.

#### 4.4. Sampling Approach

A medical history form was applied to the subjects before he is accepted as a candidate for the measurements in order to learn if the subject has any defect on his body dimensions such as a burned place or deficiency in hand, leg, finger...etc. In this context,

the form filled by the subject related to his state of health is given in the appendix which is brief medical history form. Then, only the healthy subjects were included in this study.

To meet the requirements of this study, the stratified sampling method was used to represent the whole adult male population of Turkey. Stratifying is made to that sampling included subjects from all considered 5 age groups. 7 regions of Turkey and 2 job grrops. Within each group the subjects were selected randomly. The details are in the following paragraphs.

Subjects were recruited voluntarily from the city of İstanbul (Turkey) and its surrounding areas. According to the results of Turkish Statistical Institute (TÜİK) in 2011, the 16.4 % of people who is living in Istanbul are registered into same province while the registered address of 83.6 % of them are every other provinces of Turkey. In other words, the population of this city is composed of people whose family origins are from every region of Turkey. Therefore, due to its demographic characteristics, it is assumed that the population of Istanbul approximately represents the population of Turkey.

According to the distribution of population of Turkey in 2010 presented by TÜİK, the number of people in terms of province regions is shown in Table 4.3, and the distribution ratios are in Figure 4.11:

Table 4.3. Distribution of population of Turkey based on family origin (TÜİK, 2011).

| <b>Region</b>                | <b>Population</b> |
|------------------------------|-------------------|
| <b>Black Sea</b>             | 14503651          |
| <b>Central Anatolia</b>      | 12755844          |
| <b>Eastern Anatolia</b>      | 11228932          |
| <b>Southeastern Anatolia</b> | 9230549           |
| <b>Aegean</b>                | 9089359           |
| <b>Mediterranean</b>         | 8695613           |
| <b>Marmara</b>               | 7749836           |
| <b>Total*</b>                | 73253784          |

\* In this table, the population of people registered province as Foreign Countries, which is 469204, is not taken into consideration since in the study, the number of subjects present Foreign Country were not enough to set out its anthropometric characteristics. As a total, there are 73722988 people living in Turkey.

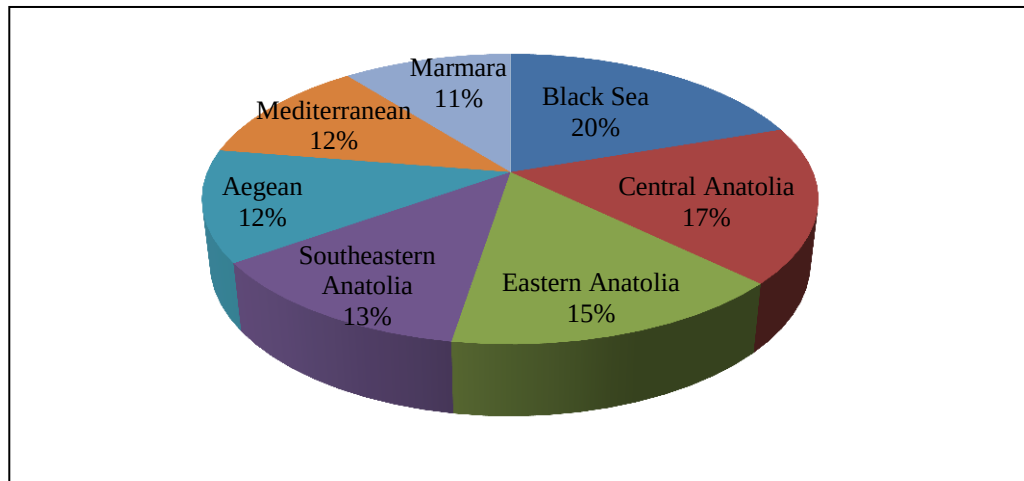


Figure 4.11. Distribution of family origin region of population of Turkey with respect to seven regions (TÜİK, 2011).

Sampling made in a way that subjects with family origin (father's origin) in each of 7 regions of Turkey were included in this study. The sample sizes from each of 7 regions are attempted to be equal as much as possible. Since age is important in anthropometry, age grouping is an essential part of such studies. In most of studies such as Sforza *et al.* (2010), and Kalichmana *et al.* (2006), there are age groups starting from 18 to above 60 years considering the change in body dimensions. So in this survey, such a grouping method was applied; and every age group is included from 18 years to above 60 years dividing the subjects into 5 age groups as following (in years): (18-29), (30-39), (40-49), (50-59) and (60 and above). Table 4.4 shows the number of people and their percentage in the age groups considering the total population and adult male population between 18 and above 60 years in terms of region of Turkey. According to Turkish Statistical Institute (2011) data of age distribution, there are 3.219.221 adult male people between 15 and 19 years of age. In order to obtain the number of people between 18 and 19 ages, it is assumed that there is a linear distribution between 15-19 aged male people. Therefore, 40% of this distribution is taken for 18-19 aged male people. Then, this age distribution is added into 19-24 and 25-29 aged adult male people distribution in order to obtain the number of male people between 18 and 29 years old as 7.763.800. Then, the age distribution of population of Turkey is shown in Figure 4.12.

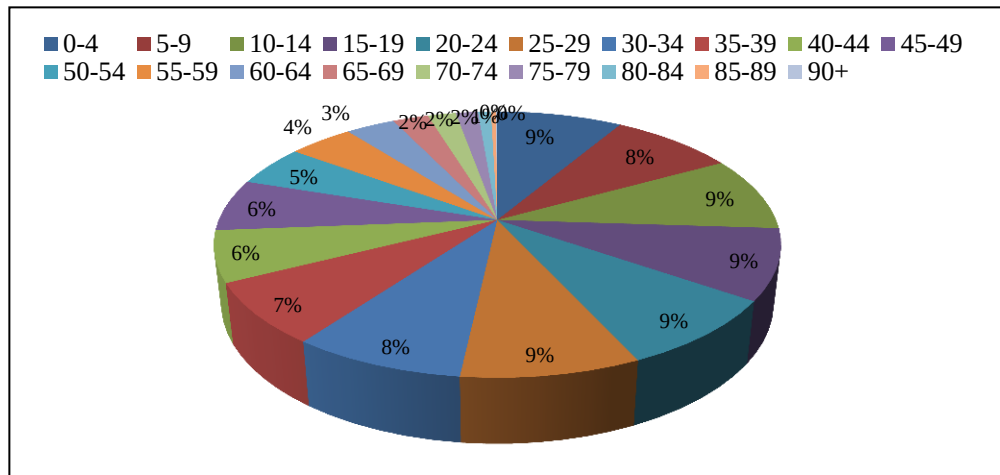


Figure 4.12. Age distribution of population of Turkey (TÜİK, 2011).

Table 4.4. Age-based distribution of total population of Turkey with male population statistics of the age groups between 18 and 70 years and their percentages (TÜİK, 2011).

| Age-groups<br>(in years) | Total population  | Male population   | Percentage of male<br>population |
|--------------------------|-------------------|-------------------|----------------------------------|
| 18-29                    | 15.216.632        | 7.763.800         | 32 %                             |
| 30-39                    | 11.776.084        | 5.945.084         | 25 %                             |
| 40-49                    | 9.295.014         | 4.703.660         | 20 %                             |
| 50-59                    | 6.970.602         | 3.486.202         | 15 %                             |
| Above 60                 | 4.159.698         | 2.039.303         | 8 %                              |
| <b>Total</b>             | <b>47.418.030</b> | <b>23.938.049</b> | <b>100 %</b>                     |

In order to analyse the job-group effect on the adult male population of Turkey, occupations are grouped into two levels as manual and non-manual workers. This grouping method is valid because of the fact that it may have masked differences in outcomes between respondents at the either end of this spectrum, i.e. between those in professional and unskilled occupations by this way (Crawley *et al.*, 2009). Also, in literature, there are many studies in which it was taken manual and non-manual workers as two occupational groupings. Most of these studies are shown in details by Tanner in 2010. Based on these studies, in this study, to investigate the effects of job type on the anthropometric characteristics, the subjects were divided into two occupation groups as manual workers and non-manual workers. This categorization was partly made by the help of the “Regulation of Heavy and Dangerous Labors” which was published in the “Turkish Official Newspaper” on 16 June 2004 and also the outcomes of ISCO-08 (2011).

#### 4.4.1. Pilot Study

A pilot study with randomly selected 100 adult male subjects based on the sampling approaches explained in previous sections was conducted before the actual study. The aims of pilot study were two-fold:

- (i) to get familiar with procedures of the study and equipment.
- (ii) to obtain the mean and standard deviation for the sample size determination of the actual study.

The overall mean and standard deviation of body dimensions for adult male subjects obtained from the pilot study are given in Table 4.5.

Table 4.5. Mean and std dev of the anthropometric measurements in the pilot study (all measurements in cm except body mass).

| No | Anthropometric measurements         | $\bar{x}(s)$   | No | Anthropometric measurements                 | $\bar{x}(s)$  |
|----|-------------------------------------|----------------|----|---------------------------------------------|---------------|
| 1  | Body mass (kg)                      | 79.68 (11.86)  | 18 | Forward fingertip reach                     | 88.21 (4.98)  |
| 2  | Stature (erect)                     | 173.36 (6.98)  | 19 | Span                                        | 175.07 (7.47) |
| 3  | Stature (normal)                    | 172.46 (6.9)   | 20 | Elbow span                                  | 91.69 (4.67)  |
| 4  | Eye height (erect)                  | 163.13 (7.14)  | 21 | Chest (bust) depth                          | 22.19 (3.09)  |
| 5  | Eye height (normal)                 | 162.29 (7.03)  | 22 | Chest (bust) breadth                        | 30.89 (5.15)  |
| 6  | Acromial (shoulder) height (erect)  | 144.86 (7.23)  | 23 | Standing elbow-to-elbow breadth             | 51.18 (4.61)  |
| 7  | Acromial (shoulder) height (normal) | 142.85 (6.75)  | 24 | Shoulder-elbow length                       | 35.83 (5.22)  |
| 8  | Elbow height (normal)               | 109.03 (5.79)  | 25 | Shoulder-fingertip length                   | 80.28 (4.99)  |
| 9  | Fingertip height (normal)           | 64.58 (4.53)   | 26 | Shoulder-grip axis length                   | 68.68 (4.91)  |
| 10 | Thumb-tip height (normal)           | 70.01 (4.54)   | 27 | Foot length                                 | 25.55 (1.59)  |
| 11 | Fist (grip axis) height (normal)    | 76.18 (5.01)   | 28 | Foot breadth                                | 9.69 (0.75)   |
| 12 | Waist height (normal)               | 100.64 (7.95)  | 29 | Sitting height(erect)                       | 91.33 (3.69)  |
| 13 | Vertical grip reach                 | 207.76 (10.27) | 30 | Sitting height (normal)                     | 90.62 (4.25)  |
| 14 | Vertical thumb-tip reach            | 212.77 (10.6)  | 31 | Sitting eye height (erect)                  | 80.71 (3.45)  |
| 15 | Vertical fingertip reach            | 219 (10.38)    | 32 | Sitting eye height (normal)                 | 80.01 (3.33)  |
| 16 | Forward grip reach                  | 74.61 (4.58)   | 33 | Sitting acromial (shoulder) height (erect)  | 62.41 (3.76)  |
| 17 | Forward thumb-tip reach             | 81.29 (5.25)   | 34 | Sitting acromial (shoulder) height (normal) | 60.76 (4.36)  |

$\bar{x}$ : mean, s: standard deviation

Table 4.5. Mean and std dev of the anthropometric measurements in the pilot study  
(cont'd).

| No | Anthropometric measurements        | $\bar{x}(s)$  | No | Anthropometric measurements             | $\bar{x}(s)$  |
|----|------------------------------------|---------------|----|-----------------------------------------|---------------|
| 35 | Sitting elbow rest height (normal) | 25.52 (4.02)  | 51 | Menton-sellion (face) length            | 12.26 (1.46)  |
| 36 | Knee height                        | 52.5 (2.87)   | 52 | Bizygomatic (face) breadth              | 12.97 (1.69)  |
| 37 | Popliteal height                   | 42.9 (3.44)   | 53 | Neck circumference                      | 38.68 (5.04)  |
| 38 | Buttock-knee length                | 60.47 (3.26)  | 54 | Chest circumference                     | 97.51 (12.54) |
| 39 | Buttock-popliteal length           | 49.71 (4.28)  | 55 | Waist circumference                     | 89.63 (14.14) |
| 40 | Thigh clearance                    | 16 (2.1)      | 56 | Hip breadth (sitting)                   | 38.46 (4.97)  |
| 41 | Buttock-leg length                 | 106.77 (4.78) | 57 | Sitting elbow-to elbow breadth (normal) | 51.53 (7.21)  |
| 42 | Sitting vertical grip reach        | 124.65(10.52) | 58 | Shoulder biacromial breadth             | 39 (1.64)     |
| 43 | Sitting vertical thumb-tip reach   | 130.68 (5.9)  | 59 | Shoulder bideltoid breadth              | 46.2 (2.65)   |
| 44 | Sitting vertical fingertip reach   | 136.69 (6.06) | 60 | Hand length                             | 18.75 (2.19)  |
| 45 | Sitting forward grip reach         | 76.37 (10.83) | 61 | Hand breadth                            | 8.68 (1.05)   |
| 46 | Sitting forward thumb-tip reach    | 81.21 (4.89)  | 62 | Palm length perpendicular               | 10.62 (1.25)  |
| 47 | Sitting forward fingertip reach    | 87.13 (5.66)  | 63 | Index finger length                     | 7.29 (0.92)   |
| 48 | Head circumference                 | 57.52 (6.07)  | 64 | Hand Circumference                      | 20.9 (2.94)   |
| 49 | Head length                        | 19.03 (2.17)  | 65 | Wrist circumference                     | 17.73 (2.71)  |
| 50 | Head breadth                       | 15.96 (1.76)  |    |                                         |               |

#### 4.4.2. Sample Size Determination

Sample size calculation is an important part of the statistical analysis. Because sample size calculation is concerned with how much data we need to make a correct decision on the study. It must be large enough to give accurate results and small enough to be collected in feasible time.

Sample size calculation formula for normative data studies is given in the ISO standards for establishing anthropometric databases as the following (ISO 15535:2006):

$$N = \left( \frac{1.96 * CV}{\alpha} \right)^2 * (1.534)^2 \quad (4.1)$$

where 1.96 is the critical Z value from a standard normal distribution for a 95% confidence interval; CV is the coefficient of variation;  $\alpha$  is the percentage of relative accuracy desired

(CI is to be no larger than  $\pm$  some percentage of the mean). Furthermore; CV is defined as the following:

$$CV = \frac{S}{\bar{x}} * 100 \quad (4.2)$$

where  $\bar{x}$  is the sample mean, and  $S$  is the sample standard deviation.

Based on the pilot study results, for each anthropometric measurement for hundred subjects, mean and standard deviation were calculated. Then, using CV and sample size were obtained. Also, relative accuracy ( $\alpha$ ) is decided to be at least 5%. Then, by using mean and standard deviation values in the pilot study, the CV values and sample sizes for subjects were calculated for each one of the anthropometric measurements. The following equations show a detailed example to demonstrate how to calculate these values for body weight.

$$CV = \frac{11.86}{79.68} * 100 \cong 14.88 \quad (4.3)$$

$$N = \left( \frac{1.96 * 14.825}{5} \right)^2 * (1.534)^2 \cong 80 \quad (4.4)$$

As a result of calculations for each dimension, the maximum N value was 101 corresponding to chest (bust) breadth. Event though 101 subjects seems satisfactory, in this study it was decided to measure 250 male subjects to increase the accuracy of the results. In other words, the desired levels of relative accuracy and confidence are achieved for all variables by measuring 250 adult male subjects.

Also, in order to check the accuracy of the equipments and get familiar with them and measurement procedures, subjects in the pilot study were measured twice and sometimes three times for each one of the body dimensions.

#### 4.4.3. Distribution of Subjects

In this study, to estimate the anthropometric characteristics of all male population of Turkey by 250 male subjects in an accurate analysis, these subjects were distributed in homogenous in terms of the region of origin city of the fathers. Then, it is attempted to include equal sample size from each of 7 regions of Turkey as much as possible. Although it was asked about their birthplace, father and mother's birthplace in order to have detailed database, the subjects were stratified based on their fathers' registered provinces. The regional distribution of family origins of the subjects is shown in Table 4.6 and Figure 4.13.

For the study, it was attempted to select equal number of subjects from each of 7 regions, each of 5 age-groups, and each of 2 job-groups as much as possible as can be seen in Table 4.6, Table 4.7, Figure 4.13 and Figure 4.14.

Table 4.6. Number of the subjects in terms of region of family origin.

| Region                | Subjects |
|-----------------------|----------|
| Aegean                | 33       |
| Marmara               | 38       |
| Black Sea             | 45       |
| Mediterranean         | 34       |
| Central Anatolia      | 35       |
| Eastern Anatolia      | 32       |
| Southeastern Anatolia | 33       |
| Total                 | 250      |

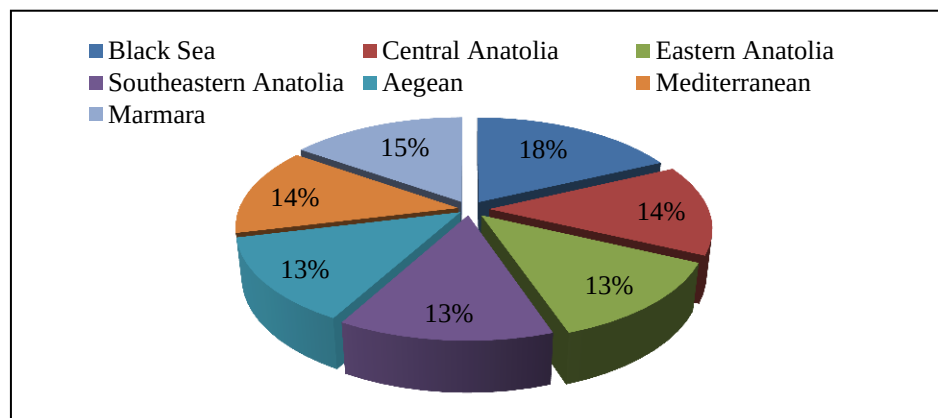


Figure 4.13. Distribution of the subjects in terms of region of family origin.

The age distribution of the subjects in the study is shown Figure 4.14.

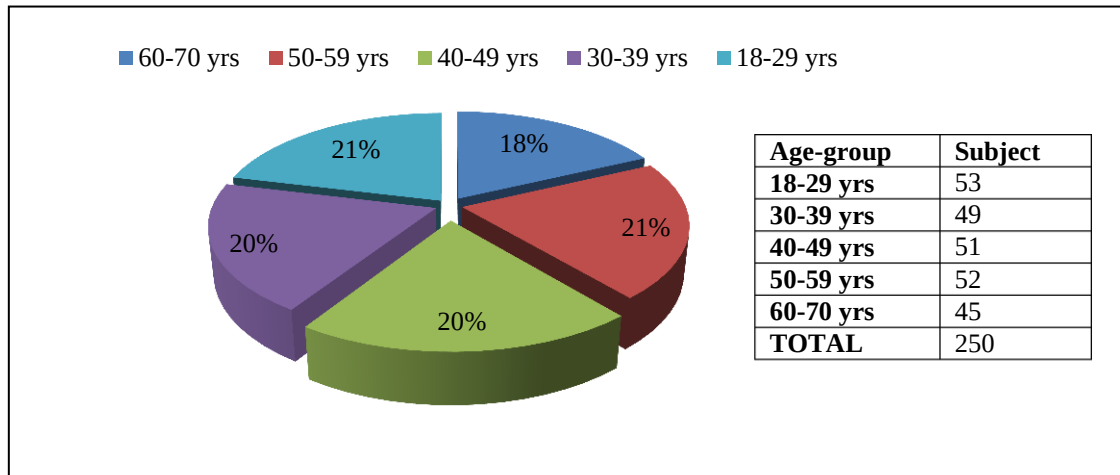


Figure 4.14. Distribution of the subjects in terms of the age groups between 18 and 70 yrs.

Table 4.7. Number of subjects in terms of occupation and age groups.\*

| Job-group         | Age-group |           |           |           |              | Total |
|-------------------|-----------|-----------|-----------|-----------|--------------|-------|
|                   | 18-29 yrs | 30-39 yrs | 40-49 yrs | 50-59 yrs | Above 60 yrs |       |
| <b>Non-Manual</b> | 34        | 21        | 23        | 26        | 19           | 123   |
| <b>Manual</b>     | 19        | 28        | 28        | 26        | 26           | 127   |

\* Students were accepted as non manual workers. Also, retired subjects were evaluated in accordance with the duration of working in the past.

Details about occupations of the subjects are given in Table 4.8;

Table 4.8. Distribution of occupations of subjects\*

| <b>Non-manual workers</b> | <b>Manual workers</b>       |
|---------------------------|-----------------------------|
| Banker (10)               | Auto mechanic (12)          |
| Business analyst (2)      | Carpenter (4)               |
| Civil engineer (5)        | Construction worker (7)     |
| Civil servant (7)         | Cook (1)                    |
| Company owner (6)         | Driver (2)                  |
| Computer engineer (6)     | Electrician (4)             |
| Computer technician (5)   | Farmer (11)                 |
| Controller (9)            | Flockman (3)                |
| Courier (1)               | Food processing worker (2)  |
| Dermatologist (1)         | Horseshoer (1)              |
| Doctor (5)                | Housepainter (2)            |
| Electric technician (8)   | Lathe operator (8)          |
| Electronics engineer (2)  | Leather industry worker (7) |

\* Number of subjects is shown in parentheses. These job-groupings were done by using the study by International Standard Classification of Occupations (ISCO-08, 2011).

Table 4.8. Distribution of occupations of subjects (cont'd).

| <b>Non-manual workers</b> | <b>Manual workers</b>       |
|---------------------------|-----------------------------|
| Graphic artist (4)        | Machine repairman (6)       |
| Human resource expert (2) | Maintenance technician (4)  |
| Industrial designer (7)   | Metal worker (3)            |
| Industrial engineer (5)   | Organic fruit farmer (1)    |
| Machine technician (10)   | Pitman (10)                 |
| Mechanical engineer (3)   | Plastic industry worker (2) |
| Pharmacist (2)            | Plumber (7)                 |
| Faculty member (1)        | Porter (2)                  |
| Sales representative (3)  | Press operator (2)          |
| Statistician (1)          | Repairman (2)               |
| Student (6)               | Dishwasher (5)              |
| Teacher (11)              | Security personel (3)       |
| Textile company owner (1) | Shop assistant (1)          |
|                           | Street seller (2)           |
|                           | Street sweeper (7)          |
|                           | Textile industry worker (3) |
|                           | Typographer (1)             |
|                           | Waiter (2)                  |

After measuring a subject, by using their body mass and stature values, the subjects can be categorized according their body mass index prime (BMIP) value which is defined as the ratio of actual BMI (body mass index) to upper limit BMI (currently defined at BMI 25). As defined, BMI Prime is also the ratio of body weight to upper body weight limit, calculated at BMI 25. Since it is the ratio of two separate BMI values, BMI Prime is a dimensionless number, without associated units. Individuals with BMI Prime < 0.74 are underweight; those between 0.74 and 0.99 have optimal weight; and those at 1.00 or greater are overweight. Body mass index prime can be obtained by the Equation 4.5. The way the classification is made is shown in Table 4.9.

$$BMIP_{Prime} = (Weight) (kg) / (25 * (Height)^2) (m)^2 \quad (4.5)$$

Table 4.9. BMIP classification and number of subjects in terms of their BMIP values.

| <b>Category</b>    | <b>BMIP range</b> | <b>Subjects</b> |
|--------------------|-------------------|-----------------|
| <b>Underweight</b> | < 0.74            | 7               |
| <b>Normal</b>      | $0.74 \leq x < 1$ | 97              |
| <b>Overweight</b>  | $\geq 1$          | 146             |
| <b>TOTAL</b>       |                   | 250             |

The minimum number of measurements that were performed by each subject is 65 and there were 250 subjects. Therefore total number of anthropometric measurement in this study is  $65 * 250 = 16250$ . The measurement of each subject has taken about 1 hour initially, and decreasing gradually to about 30 min. with experience.

#### **4.5. Measurement Procedure**

In this study, all the candidate subjects filled a “Brief Medical History Form” in Turkish (Appendix A.1 shows English version and Appendix A.2 shows Turkish version) and the ones who were free from defects on his physical development were accepted to participate in the study. The participants then signed the “Personal Consent Form” in Turkish (Appendix A.3 and Appendix A.4). The “Personal Consent Form” and “Medical History Form” were prepared both in English and Turkish.

Next, the subjects filled a “Personal Data Form” (Appendix A.5), which included questions like age, occupation, the city the subject lives now, family origin, and mother and father’s birthplace. Part of the information related to this form (e.g., stature, body mass, eye height, sitting popliteal height, hand length) is filled by the investigator after the measurements.

Before starting the tests, as a last step, the subjects were asked to read “Instructions” in Turkish (Appendix A.6 shows English version and Appendix A.7 shows Turkish version) in order to be familiar the procedure of the study.

All body dimensions during the study were measured in the Boğaziçi University Ergonomics Labaratuary (ErgoLab). The position of the subject is determined for each anthropometric measurement according to the National Health and Nutrition Examination Survey and ISO procedures.

- For the weight measurements, the following steps are followed:
  - (i) Scale is zeroed and person wears minimal clothing. Watch, jewelry and other object are removed. Pockets are emptied.

- (ii) Shoes off and person stands on the middle of the scale with feet close and arms on the side close to the body. Body weight is distributed evenly on both feet.
- (iii) Person stands still, looking straight ahead, and then measurement is taken.

- For the standing measurements, the following steps are followed:

- (i) Shoes off and heels together with toes are pointing out about 60 degree angle and heels are touching on the base of the vertical back board of the stadiometer.
- (ii) Body weight is distributed evenly on both feet. Arms and shoulders are relaxed.
- (iii) Shoulder blades and buttock are touching on the vertical board.
- (iv) Head is aligned so that Frankfurt Plane is parallel to the floor and perpendicular to the vertical board (for some people all body points may not touch on the board) as can be seen in Figure 4.15.
- (v) All head ornaments etc. on top of the head are removed.
- (vi) Person looks straight ahead. For erect position, subject takes a deep breath and holds it and stands as tall as possible (Deep breath forces spine to be more straight). For normal positions, subject is relaxed while breathing normally.
- (vii) Move the sliding board of the stadiometer so that it is firmly touching the head (Hair is compressed); and then measurement is taken. This posture can be seen in detail in Figure 4.16:

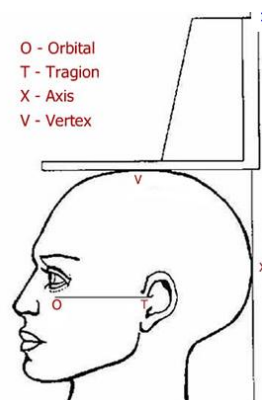


Figure 4.15. Orientation of head in the Frankfurt Plane (Ross *et al.*, 2003).

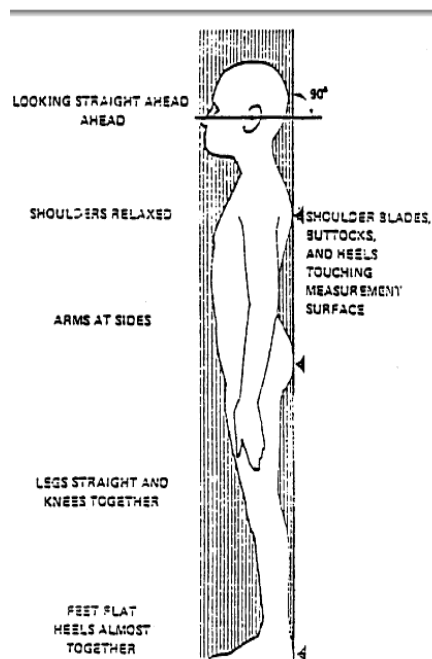


Figure 4.16. The standing posture (Lohman *et al.*, 1988; Rockville, 1988).

- For the sitting measurements, the following steps are followed:
  - (i) Subject sits while torso is making 90 degree angle with upper legs and knee is in 90 degree angle while feet are firmly touching on the floor or board.
  - (ii) Buttock touching on the vertical board of the stadiometer.
  - (iii) Shoulder blades are touching on the vertical board.
  - (iv) Head is aligned in the Frankfurt Plane that is parallel to the floor and perpendicular to the vertical board (for some people all body points may not touch on the board).
  - (v) All head ornaments etc. on top of the head are removed.
  - (viii) Person looks straight ahead. For erect position, subject takes a deep breath and holds it and stands as tall as possible (Deep breath forces spine to be more straight). For normal positions, subject is relaxed while breathing normally.
  - (vi) For stature measurement, move the sliding board of the stadiometer so that it is firmly touching the head (hair is compressed), and then measurement is taken. The seated posture can be seen in detail in Figure 4.17.

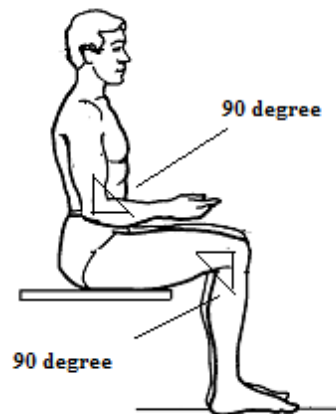


Figure 4.17. The seated posture (NASA-STD-3000, 1981).

- For the measurements related to circumferences, the following steps have to be provided:
  - (i) It is important to be certain that the muscle of the arm is not flexed or tightened which could yield a larger and inaccurate reading.
  - (ii) The technician stands to the dominant side of the subject.
  - (iii) The measuring tape is held gently on the skin surface.
  - (iv) The two ends of the overlapping tape are pulled together using care not to compress the skin and the underlying subcutaneous tissue, and the measure is recorded (National Health and Nutrition Examination Survey, 2007).

Most of standing measurements such as stature, eye height, shoulder height, elbow height, waist height, hip height, fist-grip axis height and knee height, and all the vertical reach positions including span and elbow span measurements were measured by grid board, stadiometer and ultrasonic measuring unit. For these measurements, the subject with shoes-off stood still with his shoulders and hip touching the wall and eyes looking forward. For seated measurements, sitting height table was used. Breadth and some length dimensions were taken by antropometers and calipers whereas the circumferences were measured by measuring tapes.

Upper and lower extremity measurements were taken from the dominant side of the subject. In this study, some of these measurements had to be taken in standing posture, and

the others were taken in sitting positions as given in Figure 4.18, Figure 4.19, Figure 4.20 and Figure 4.21.



Figure 4.18. Position for the vertical dimensions in stand. obtained by stadiometer.



Figure 4.19. Position for the vertical dimensions in sitting obtained by sitting height table.



Figure 4.20. Position for the forward dimensions in standing obtained by grid board and handle diameter.



Figure 4.21. Position for the vertical dimensions in standing obtained by grid board.

For foot and hand measurements, small anthropometers and calipers were used since there were small length and breadth measurements. These anthropometric measurements were obtained as given in Figure 4.22 and Figure 4.23 related to measurements of foot breadth and hand length.

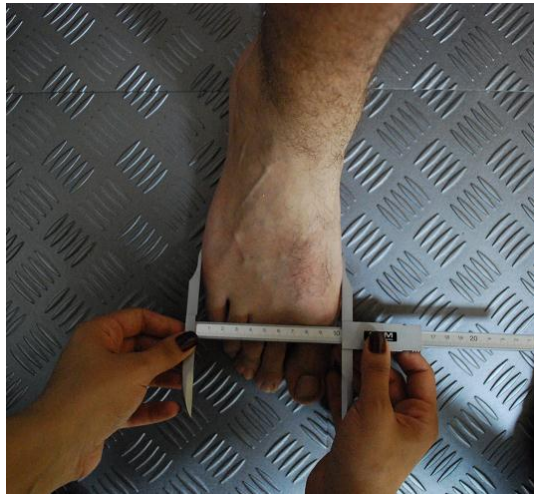


Figure 4.22. Measurement of foot breadth obtained by caliper.

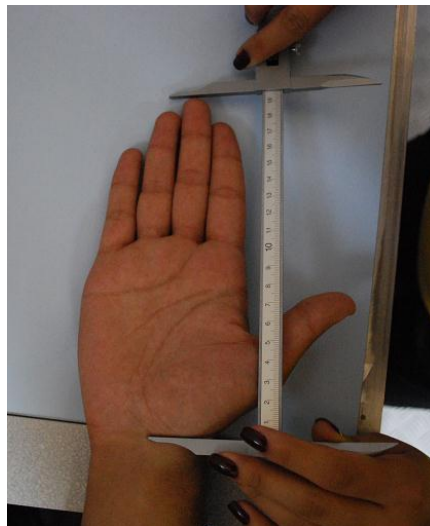


Figure 4.23. Measurement of hand length obtained by caliper.

For the circumference measurements, measuring tapes were used. By this context, head, hand, wrist, neck, chest and waist circumferences were measured as given in Figure 4.24 for the measurement of neck circumference.



Figure 4.24. Measurement of neck circumference obtained by measuring tape.

In order to speed up the process there were some executions as the following:

- (i) To minimize movements, subjects firstly measured in standing. After taking the standing measurements, the second part of measurements were related to seated measurements. The circumference measurements were obtained at the end of the each study.
- (ii) All the measurements were performed by right hand of the experimenter which is dominant.

## 4.6. Statistical Methods

### 4.6.1. Statistical Variables

Table 4.10. Independent factors to be investigated.

| Independent factors | Level                                                                                                                                                                   |
|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Age-group</b>    | (i) 18-29 years<br>(ii) 30-39 years<br>(iii) 40-49 years<br>(iv) 50-59 years<br>(v) 60-70 years                                                                         |
| <b>Job-group</b>    | (i) Non-manual worker<br>(ii) Manual worker                                                                                                                             |
| <b>BMIP-group</b>   | (i) Underweight (BMIP of the subject is less than 0.74)*<br>(ii) Normal (BMIP of the subject is between 0.74 to 1)<br>(iii) Overweight (BMIP of the subject is above 1) |

\* Underweight people are excluded for statistical analysis since there was only seven underweight subjects.

One of the objectives of this study is to investigate the effects of age-group, job-group and BMIP-group on some of the measured dimensions (response variables). These independent factors of the study are shown in Table 4.10.

#### 4.6.2. Statistical Analysis

Statistical Analysis was performed using Minitab 16.0. In the analysis, p-values  $\leq 0.05$  were accepted as significant and  $0.05 < \text{p-values} \leq 0.1$  was accepted as marginal.

4.6.2.1. Descriptive Statistics for Age-Groups, Job-Groups and BMIP-Groups. After finishing all the measurements, descriptive statistics such as mean, standard deviation, range and percentiles (5<sup>th</sup>, 50<sup>th</sup> and 95<sup>th</sup>) were calculated. Pearson's correlation coefficient was used to investigate the strength of linear relationship between variables.

4.6.2.2. Inferential Statistics. There are some different types of inferential statistics used in this study as following:

(i) For testing the equality of means of the responses for treatments including BMIP-group, job-group and age-group, three-way analysis of variance (ANOVA) was used. While using ANOVA, the following three assumptions were stratified.

- The error terms (residuals) of the model must follow a normal distribution centered at zero ( $\epsilon \sim \text{NID Normal}(0, \sigma^2)$ ) (normality assumption).
- There must not be any correlation between error terms (correlation of each value and the value before it) and correlation between independent variables and error terms (autocorrelation between residuals).
- The variances of response variables for each treatment must not be different from each other (homogeneity assumption).

For adult male subjects, normality of the residuals of anthropometric data was tested by using Anderson-Darling normality test and normal probability plot of the residuals. Thus, it was found that they approximately follow normal distribution for all independent variables. Secondly, to check autocorrelation between residuals, Pearson's correlation

between residuals for each anthropometric measurement were calculated, and it was proven that they were independent to each other. After that, for homogeneity assumption, Bartlett's test was used to see that the sample variances in each treatment were not statistically different. For the same purpose, plot of residuals versus the fitted response were investigated for the whole adult male subjects. Therefore, after meeting the three assumptions of ANOVA, it was used to investigate if the independent variables have an effect on each anthropometric measurement.

The hypothesis in ANOVA is that the means of the groups are equal as given in Equation 4.6 (Montgomery, 2005):

$$\begin{aligned} H_0: \mu_i &= \mu_j \\ H_1: \mu_i &\neq \mu_j \end{aligned} \quad (4.6)$$

where  $i$  and  $j$  are treatments ( $i \neq j$ ) and in this study, there were 3 treatment groups as age-groups, job-groups and BMIP-groups for each one of the anthropometric measurements. By this context, if the null hypothesis is true, it means that these 3 groups have equal means.

In this study, there is no significant interaction effect. The mathematical model that describes the relationship between response and treatment for three-way ANOVA is given as following (Montgomery, 2005):

$$y_{ijk} = \mu + \alpha_i + \chi_j + \delta_k + \varepsilon_{ijk} \quad (4.7)$$

where,

$y_{ijk}$ :  $ijk^{th}$  response (body dimension)

$\mu$ : overall response mean

$\alpha_i$ : effect of  $i^{th}$  level for age-group factor

$\chi_j$ : effect of  $j^{th}$  level for job-group factor

$\delta_k$ : effect of  $k^{th}$  level for BMIP-group factor (excluded underweight people)

$\varepsilon_{ijk}$ : NID  $(0, \sigma^2)$  random error component

(ii) After ANOVA, multiple comparison tests were performed. Tukey's test was used for post-hoc analysis. This is because while making pair wise comparisons, the Tukey's method results in a narrower confidence limit, which is preferable (Toothaker, 1993). Moreover, because of its simplicity and nearly accurate control of the overall error rate, Tukey's test is recommended for pair wise comparisons (Hochberg and Tamhane, 1987). The hypothesis of this test is as the following (Montgomery, 2005):

$$\begin{aligned} H_0: \mu_i &= \mu_j \\ H_1: \mu_i &\neq \mu_j \end{aligned} \quad (4.8)$$

where  $i$  and  $j$  are treatment levels ( $i \neq j$ ). Tukey's procedure makes use of the distribution of the studentized range statistic which is equal to (Montgomery, 2005):

$$q = \frac{\bar{y}_{max} - \bar{y}_{min}}{\sqrt{MS_E/n}} \quad (4.9)$$

where  $\bar{y}_{max}$  and  $\bar{y}_{min}$  are the largest and the smallest sample means,  $MS_E$  is mean squares due to error and  $n$  is the sample size. Due to  $q$  value,  $T$  value of Tukey's test for unequal sample sizes can be calculated as (Montgomery, 2005)

$$T_\alpha = \frac{q_\alpha(p,f)}{\sqrt{2}} \sqrt{MS_E \left( \frac{1}{n_i} + \frac{1}{n_j} \right)} \quad (4.10)$$

where  $q_\alpha(p, f)$  is the upper  $\alpha$  percentage points of studentized range statistics ( $q$ ),  $f$  is the number of degrees of freedom associated with the  $MS_E$ ,  $p$  is the number of groups will be compared,  $n_i$  and  $n_j$  are the sample sizes of the groups. Moreover, a set of  $100(1 - \alpha)$  confidence intervals for all pairs of means can be constructed as follows (Montgomery, 2005):

$$\bar{y}_i. - \bar{y}_j. - \frac{q_\alpha(p,f)}{\sqrt{2}} \sqrt{MS_E \left( \frac{1}{n_i} + \frac{1}{n_j} \right)} \leq \mu_i - \mu_j \leq \bar{y}_i. - \bar{y}_j. + \frac{q_\alpha(p,f)}{\sqrt{2}} \sqrt{MS_E \left( \frac{1}{n_i} + \frac{1}{n_j} \right)} \quad (4.11)$$

where  $\bar{y}_i.$  and  $\bar{y}_j.$  are the sample means of  $i^{th}$  and  $j^{th}$  groups and  $\mu_i$  and  $\mu_j$  are the population means of  $i^{th}$  and  $j^{th}$  groups ( $i \neq j$ ).

(iii) For erect and normal positions of some anthropometric measurements, paired t-test was used for comparing sample means since it can be more powerful than a two sample t-test. This is because a paired t-test is not subject to the additional variation arising from the independence of the observations. Also, a paired t-test does not require both samples to have equal variance. Therefore, for analyzing differences between two treatments given to the same subject, paired t-test is useful to gain more statistical power (Minitab Inc., 2008). The hypotheses of paired t-test are (Montgomery, 2005):

$$\begin{aligned} H_0: \mu_d &= 0 \\ H_1: \mu_d &\neq 0 \end{aligned} \quad (4.12)$$

where  $\mu_d$  is the difference of the mean between two groups. The test statistic for this hypothesis is as the following;

$$t_0 = \frac{\bar{d}}{s_d/\sqrt{n}} \quad (4.13)$$

where the sample mean of the differences is as following;

$$\bar{d} = \frac{1}{n} \sum_{j=1}^n d_j \quad (4.14)$$

Here, the sample standard deviation of the differences is as the following;

$$s_d = \sqrt{\frac{\sum_{j=1}^n (d_j - \bar{d})^2}{n-1}} \quad (4.15)$$

where  $n$  is the sample size, and  $d_j$  is the  $j^{th}$  paired difference (Montgomery, 2005).

(iv) The hypothesis of a general t-test is stated as (Montgomery, 2005):

$$\begin{aligned} H_0: \mu_1 &= \mu_2 \\ H_1: \mu_1 &\neq \mu_2 \end{aligned} \quad (4.16)$$

where  $\mu_1$  and  $\mu_2$  are means of group 1 and 2. The test statistic is calculated as:

$$t_0 = \frac{\bar{y}_1 - \bar{y}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \quad (4.17)$$

where  $\bar{y}_1 - \bar{y}_2$  are the sample means,  $n_1$  and  $n_2$  are the sample sizes,  $S_1^2$  and  $S_2^2$  are the sample variances. The distribution of  $t_0$  is well approximated by  $t$  if we use;

$$v = \frac{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)^2}{\frac{\left(\frac{s_1^2}{n_1}\right)^2}{n_1 - 1} + \frac{\left(\frac{s_2^2}{n_2}\right)^2}{n_2 - 1}} \quad (4.18)$$

(v) Regression analysis was made to develop prediction equations for anthropometric measurements. Regression models were firstly obtained by four variables including stature, body mass, age and job-group. Then by using stepwise regression approach, regression models with independent variables were found which maximize  $R_{adj}^2$  values considering  $C_p$  as well.

In this study, the relation between independent variables and each one of anthropometric measurements was found as liner. Thus, multiple linear models were used in the statistical analysis of this study. The general form of the multiple linear regression equation is as the following (Montgomery, 2005):

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \cdots + \beta_k x_k + \epsilon \quad (4.19)$$

where

|                                             |                                                           |
|---------------------------------------------|-----------------------------------------------------------|
| $\beta_0$                                   | : Constant                                                |
| $\beta_1, \beta_2, \beta_3, \dots, \beta_k$ | : Regression coefficients for independent variables,      |
| $x_1, x_2, x_3, \dots, x_k$                 | : Regressor variables,                                    |
| $\epsilon$                                  | : Error term ( $\epsilon \sim \text{NID}(0, \sigma^2)$ ). |

Before starting the regression analysis, the following assumptions are met (Montgomery, 2005):

- **Linearity:** The relationship between the dependent and independent variables should be linear. Multiple regression procedures are not greatly affected by minor deviations from this assumption.
- **Normality:** The residuals of the independent variables must be normally distributed. This assumption can be checked by looking at the normal probability plots of residuals.
- **Multicollinearity must not exist:** If it exists, it means that there are redundant variables in the regression. This can be checked by looking at the variance inflation factor (VIF). VIF is desired to be smaller than 5.
- **Variance homogeneity:** The variances within groups must be equal. Bartlett's test can be used to check this assumption.
- **Autocorrelation:** There must not be correlation between the errors because correlation affects the estimation of coefficients for the regression. Durbin-Watson statistic is used to verify this assumption. It is desired to be between 1.5 and 2.5.

After regression models were determined, a test for significance of regression was performed to check the goodness of model (Montgomery, 2005).

The model utility test is performed for checking the significance of the model. The hypothesis of this test is:

$$\begin{aligned} H_0: \beta_1 = \beta_2 = \beta_3 = \dots = \beta_n = 0 \\ H_1: \beta_j \neq 0 \text{ for at least } j \ (j = 1, 2, \dots, n) \end{aligned} \quad (4.20)$$

Rejection of  $H_0$  in the above hypothesis implies that at least one of the regressor variables contributes significantly to the model. An ANOVA table, which considers the total sum of squares, sum of squares due to regression model and sum of squares due to residual, is used for checking the significance of regression model. If the p-value is less than  $\alpha$  significance level, the null hypothesis  $H_0$  is rejected, which implies that at least one of the regressor variables contributes significantly to the model (Montgomery, 2005).

Moreover  $R^2$  and  $R_{adj}^2$  values were examined to see the goodness of fit of the regression model.  $R^2$  is the proportion of variance in the dependent variable, which can be explained by the independent variables and  $R_{adj}^2$  is used to penalize the addition of extraneous predictors to the model. The higher  $R_{adj}^2$  values indicate that the included independent variables describe the dependent variable better, thus the fit of the model is better (Bruin, 2011). Moreover, percentile values of each anthropometric measurement were also calculated for adult male subjects for each age and job groups.

## **5. RESULTS**

### **5.1. Descriptive Statistics**

#### **5.1.1. Mean, Standard Deviation and Range of Variables**

The means, standard deviations and ranges for each one of the anthropometric measurements stratified by age-group, job-group and BMIP-group were calculated. Table 5.1 shows anthropometric measurements stratified by age-group; Table 5.2 indicates anthropometric measurements stratified by job-group and Table 5.3 figures out anthropometric measurements stratified by BMIP-group (Here, underweight people were excluded since there were only 7 underweight in subject which is not enough to make accurate conclusions about the results).

According to the results of Table 5.1, the people at their 30s are heavier than other groups while those at their 20s are tallest. Table 5.2 indicated that non-manual workers are heavier and taller than manual workers. The measurements given in Table 5.3 show that overweight male people are heavier by almost 15 kg than normal weight people. In this statistical analysis, underweight people were excluded since there were only 7 people in this study.

Table 5.1. Anthropometric measurements stratified by age-group (all in cm except body mass).

| No | Measurement         | Overall (n=250) |               | 18-29 years (n=53) |             | 30-39 years (n=49) |             | 40-49 years (n=51) |             | 50-59 years (n=52) |             | 60-70 years (n=53) |             |
|----|---------------------|-----------------|---------------|--------------------|-------------|--------------------|-------------|--------------------|-------------|--------------------|-------------|--------------------|-------------|
|    |                     | $\bar{x}$ (s)   | min – max     | $\bar{x}$ (s)      | min – max   | $\bar{x}$ (s)      | min – max   | $\bar{x}$ (s)      | min – max   | $\bar{x}$ (s)      | min – max   | $\bar{x}$ (s)      | min – max   |
| 1  | Body mass (kg)      | 76.6 (12.8)     | 50.0- 128.0   | 75.5 (10.8)        | 54.0-102.0  | 79.9 (13.35)       | 58.0-128.0  | 77.8 (13.2)        | 54.0-108.0  | 76.8 (13.2)        | 50.0-103.0  | 72.8 (12.8)        | 55.0-105.0  |
| 2  | Stature (e)         | 171.5 (8.1)     | 153.3 - 189.5 | 176.8 (7.1)        | 157.6-189.4 | 174.7 (6.6)        | 159.0-189.5 | 171.3 (7.4)        | 154.0-185.6 | 168.5 (6.8)        | 155.7-181.0 | 165.2 (7.1)        | 153.3-181.8 |
| 3  | Stature (n)         | 171.1(8.0)      | 152.2 - 189.3 | 176.2 (7.0)        | 157.5-188.4 | 174.3 (6.6)        | 158.9-189.3 | 171.0 (7.3)        | 153.7-185.2 | 168.1 (6.7)        | 155.5-179.9 | 165.0 (7.1)        | 152.2-181.7 |
| 4  | Eye ht (e)          | 160.7 (8.2)     | 142.3 - 180.7 | 165.6 (7.6)        | 147.5-180.7 | 164.3 (6.7)        | 148.2-178.5 | 160.4 (7.4)        | 142.5-175.5 | 157.7 (6.8)        | 145.6-170.5 | 154.6 (7.4)        | 142.3-171.2 |
| 5  | Eye ht (n)          | 160.3 (8.1)     | 142.0 - 180.5 | 165.0 (7.5)        | 147.4-180.5 | 163.9 (6.7)        | 148.1-178.3 | 160.1 (7.3)        | 142.5-175.1 | 157.4 (6.7)        | 145.4-170.1 | 154.4 (7.4)        | 142.0-171.1 |
| 6  | Acr. (shld) ht (e)  | 142.8 (7.5)     | 126.7 - 167.4 | 146.4 (7.1)        | 132-167.4   | 146.5 (6.9)        | 131.4-161.7 | 142.8 (7.1)        | 128.0-159.4 | 140.0 (6.6)        | 129.4-161.1 | 137.8 (6.0)        | 126.7-153.4 |
| 7  | Acr. (shld) ht (n)  | 141.2 (7.1)     | 125.9 - 160.6 | 144.3 (6.7)        | 131.2-160.6 | 144.9 (6.7)        | 130.5-158.5 | 141.1 (6.7)        | 127.3-158.8 | 138.6 (6.1)        | 128.5-150.4 | 136.8 (6.1)        | 125.9-152.6 |
| 8  | Elbow ht (n)        | 106.2 (6.1)     | 92.4 - 125.4  | 109.5 (5.1)        | 100.6-125.4 | 108.1 (5.4)        | 95.0-119.5  | 105.6 (6.3)        | 93.0-117.6  | 104.5 (5.5)        | 96.2-119.6  | 102.9 (6.1)        | 92.4-120.1  |
| 9  | Fngtip ht (n)       | 63.8 (4.4)      | 52.5 - 78     | 65.8 (3.5)         | 58.7-73.3   | 65.4 (4.1)         | 55.1-72.6   | 63.5 (4.2)         | 55.0-71.3   | 63.0 (4.9)         | 53.9-78.0   | 60.9 (3.9)         | 52.5-67.4   |
| 10 | Th-tip ht (n)       | 69.2 (4.4)      | 58.3 - 81.2   | 71.3 (3.7)         | 63.0-77.5   | 70.6 (4.8)         | 60.3-77.6   | 68.6 (3.9)         | 58.3-75.4   | 68.3 (4.8)         | 58.326-81.2 | 67.2 (3.7)         | 59.4-75.0   |
| 11 | Knuckle ht (n)      | 75.8 (4.8)      | 63.3 - 91.4   | 77.8 (3.9)         | 70.1-91.4   | 77.2 (4.9)         | 66.0-85.0   | 75.3 (4.3)         | 66.2-86.0   | 74.5 (5.5)         | 64.9-87.9   | 73.9 (4.3)         | 63.3-82.9   |
| 12 | Waist ht (n)        | 102.7 (7.0)     | 67.7 - 120.8  | 103.1 (5.4)        | 92.3-117.9  | 105.2 (7.1)        | 90.5-119.9  | 102.7 (6.7)        | 91.2-120.8  | 101.7 (7.6)        | 79.5-115.2  | 100.9 (7.7)        | 67.7-118.0  |
| 13 | Vertical grip rch   | 203.9 (11.0)    | 178 - 232.9   | 210.7 (8.5)        | 193.7-232.9 | 208.1 (9.1)        | 186.5-229.1 | 203.1(11.4)        | 181.0-228.9 | 199.4 (10.4)       | 182.2-225.5 | 197.2 (9.7)        | 178.0-221.3 |
| 14 | Vertical th-tip rch | 209.0 (11.3)    | 180.4 - 240.1 | 215.3 (9.1)        | 199.3-240.1 | 213.3 (9.2)        | 190.8-234.6 | 208.7(11.8)        | 186.3-235.8 | 204.2 (10.6)       | 186.5-231.0 | 202.6(10.2)        | 180.4-225.6 |
| 15 | Vertical fngtip rch | 214.9 (11.5)    | 183.2 - 244.6 | 221.9 (8.7)        | 204.7-244.6 | 219.2 (9.2)        | 196.5-239.9 | 214.2(11.7)        | 188.6-241.0 | 209.9 (10.9)       | 190.4-238.4 | 208.7(11.0)        | 183.2-232.1 |
| 16 | Forward grip rch    | 74.1 (4.2)      | 63.7 - 85.5   | 75.1 (4.4)         | 64.5-85.5   | 74.7 (4.3)         | 65.0-84.1   | 74.2 (4.2)         | 64.7-84.3   | 74.0 (4.1)         | 64.5-84.5   | 72.5 (3.8)         | 63.7-80.4   |
| 17 | Forward th-tip rch  | 80.1 (4.8)      | 68.2 – 95     | 80.9 (5.1)         | 69.6-95.0   | 80.5 (4.8)         | 72.0-89.4   | 80.5 (4.6)         | 68.2-90.4   | 79.8 (4.8)         | 72.3-91.694 | 78.5 (4.4)         | 70.3-91.1   |
| 18 | Forward fngtip rch  | 86.6 (4.8)      | 73 - 98.5     | 88.1 (4.9)         | 75.184-96.6 | 87.5 (4.6)         | 77.2-98.5   | 86.9 (4.7)         | 73.0-96.4   | 85.8 (4.7)         | 77.3-96.0   | 84.5 (4.5)         | 76.6-96.1   |
| 19 | Span                | 173.0 (8.6)     | 149.8 - 198.2 | 177.1 (7.6)        | 155.6-190.8 | 176.6 (6.4)        | 160.8-189.3 | 173.5 (8.2)        | 153.9-198.2 | 170.1 (7.5)        | 150.7-183.7 | 167.2 (9.0)        | 149.8-188.9 |
| 20 | Elbow span          | 90.4 (5.2)      | 75.8 - 104.7  | 91.9 (4.4)         | 83.06-101.2 | 92.4 (4.3)         | 83.5-100.6  | 90.9 (5.6)         | 80.8-104.7  | 88.9 (5.1)         | 79.8-104.4  | 87.5 (4.9)         | 75.8-98.5   |
| 21 | Chest (bust) depth  | 22.4 (2.6)      | 16.6 - 29.5   | 21.9 (1.9)         | 17.3-26.5   | 22.6 (2.4)         | 18.7-29.5   | 22.1 (1.8)         | 19.5-26.5   | 22.7 (2.2)         | 17.8-28.0   | 22.7 (2.4)         | 16.6-28.5   |
| 22 | Chest (bust) brt    | 30.4 (3.5)      | 24.4 - 44.5   | 30.8 (3.3)         | 25.7-44.5   | 31.0 (2.8)         | 26.0-38.0   | 30.4 (3)           | 24.4-36.5   | 30.2 (2.7)         | 24.6-37.6   | 29.5 (2.4)         | 24.4-34.3   |
| 23 | Stand. e-to-e brt   | 50.8 (4.8)      | 40 - 66.3     | 50.2 (4.5)         | 40.5-58.5   | 52 (5.4)           | 41.4-66.3   | 50.6 (4.4)         | 40.0-60.3   | 51.2 (4.1)         | 42.1-59.1   | 49.8 (5.3)         | 42.0-65.6   |

Table 5.1. Anthropometric measurements stratified by age-group (cont'd).

| No | Measurement             | Overall (n=250) |               | 18-29 years (n=53) |             | 30-39 years (n=49) |             | 40-49 years (n=51) |             | 50-59 years (n=52) |             | 60-70 years (n=53) |            |
|----|-------------------------|-----------------|---------------|--------------------|-------------|--------------------|-------------|--------------------|-------------|--------------------|-------------|--------------------|------------|
|    |                         | $\bar{x}$ (s)   | min – max     | $\bar{x}$ (s)      | min – max   | $\bar{x}$ (s)      | min – max   | $\bar{x}$ (s)      | min – max   | $\bar{x}$ (s)      | min – max   | $\bar{x}$ (s)      | min – max  |
| 24 | Shld-elbow lgt          | 36.6 (4.4)      | 20.0 - 53.5   | 36.8 (4.6)         | 24.4-52.6   | 38.4 (4.8)         | 28.7-53.5   | 37.2 (3.8)         | 29.1-51.6   | 35.6 (3.6)         | 25.2-46.6   | 34.9 (4.1)         | 20.0-42.4  |
| 25 | Shld-fngtip lgt         | 79.0 (5.3)      | 66.3 - 97.6   | 80.6 (5.5)         | 71.8-96.5   | 81.1 (5.7)         | 67.5-97.6   | 79.4 (5.1)         | 70.1-90.1   | 77.0 (4.2)         | 66.3-89.3   | 76.9 (4.6)         | 68.8-88.1  |
| 26 | Shld-fist lgt           | 67.0 (5.6)      | 52.5 - 87.3   | 68.5 (5.6)         | 60.4-87.3   | 69.3 (5.0)         | 59.6-81.8   | 67.6 (5.5)         | 56.8-81.5   | 65.5 (5.0)         | 56.0-79.2   | 63.9 (5.5)         | 52.5-74.5  |
| 27 | Foot lgt                | 25.6 (1.5)      | 20.2 - 29.1   | 25.7 (1.7)         | 20.7-28.7   | 25.9 (1.5)         | 20.2-28.6   | 25.6 (1.6)         | 21.6-29.1   | 25.5 (1.2)         | 22.6-28.3   | 25.1 (1.5)         | 22.7-29.0  |
| 28 | Foot brt                | 9.9 (0.8)       | 8.0 - 11.9    | 9.8 (0.8)          | 8.2-11.4    | 9.8 (0.7)          | 8.1-11.4    | 9.8 (0.9)          | 8.0-11.9    | 10.1 (0.8)         | 8.4-11.2    | 9.8 (0.8)          | 8.5-11.7   |
| 29 | Sit. ht(e)              | 90.2 (3.9)      | 76.6 - 100.9  | 92.0 (3.9)         | 83.6-100.9  | 91.2 (3.9)         | 84.6-99.4   | 90.4 (3.7)         | 76.6-95.5   | 88.7 (3.2)         | 82-.095.7   | 88.5 (3.5)         | 76.7-98.9  |
| 30 | Sit. ht (n)             | 89.8 (3.9)      | 76.3 - 99.9   | 91.4 (4.1)         | 82.0-99.9   | 90.8 (3.9)         | 83.8-99.3   | 90.1 (3.6)         | 76.3-95.1   | 88.4 (3.2)         | 82.0-95.6   | 88.2 (3.5)         | 76.3-98.7  |
| 31 | Sit. eye ht (e)         | 79.7 (4.0)      | 66.0 - 91.2   | 81.6 (3.7)         | 73.5-89.5   | 80.5 (3.9)         | 74.0-91.2   | 80.0 (3.9)         | 66.4-90.0   | 78.2 (3.4)         | 71.6-85.9   | 77.9 (3.7)         | 66.0-88.6  |
| 32 | Sit. eye ht (n)         | 79.3 (4.0)      | 65.6 - 90.9   | 81.0 (3.9)         | 73.2-89.4   | 80.1 (3.9)         | 73.2-90.9   | 79.7 (3.9)         | 66.1-89.6   | 77.8 (3.3)         | 71.3-85.8   | 77.6 (3.7)         | 65.6-88.4  |
| 33 | Sit. acr. (shld) ht (e) | 61.7 (3.8)      | 50.6 - 82.3   | 63.0 (4.3)         | 56.0-78.5   | 62.6 (4.4)         | 54.5-82.3   | 61.6 (3.2)         | 50.6-65.8   | 61.0 (3.3)         | 55.5-69.4   | 60.4 (3.2)         | 52.7-68.0  |
| 34 | Sit. acr. (shld) ht (n) | 60.4 (3.9)      | 49.1 – 79.0   | 61.4 (4.8)         | 52.0-79.0   | 61.2 (4.4)         | 49.1-77.6   | 60.1 (3.3)         | 50.0-65.0   | 59.9 (3.2)         | 54.7-68.8   | 59.3 (3.1)         | 52.0-66.6  |
| 35 | Sit. elbow rest ht (n)  | 26.4 (3.4)      | 15.5 - 36.5   | 25.4 (3.1)         | 19.4-31.6   | 26.2 (3.5)         | 15.5-36.5   | 26.6 (2.4)         | 19.7-31.6   | 26.8 (2.6)         | 22.4-33.4   | 27.1 (2.7)         | 20.3-33.1  |
| 36 | Knee ht                 | 51.3 (3.3)      | 44.8 – 68.0   | 53.1 (2.6)         | 46.9-59.4   | 52.3 (2.6)         | 47.3-59.6   | 51.1 (3.8)         | 44.8-68.0   | 50.5 (3.1)         | 45.9-57.8   | 49.4 (2.6)         | 45.2-55.7  |
| 37 | Popliteal ht            | 42.2 (3.2)      | 33.9 - 56.5   | 43.5 (2.8)         | 35.2-50.1   | 43.0 (3.0)         | 33.9-50.9   | 42.5 (3.5)         | 36.5-56.5   | 41.5 (3.4)         | 34.0-49.0   | 40.4 (2.3)         | 36.5-45.2  |
| 38 | Buttock-knee lgt        | 59.8 (3.5)      | 47.62 - 67.1  | 60.2 (3.3)         | 47.62-66.4  | 61.5 (3.6)         | 52.8-67.1   | 59.4 (3.2)         | 50.8-65.5   | 59.3 (3.3)         | 52.6-65.8   | 58.5 (3.5)         | 52.8-67.0  |
| 39 | Buttock-popliteal lgt   | 49.8 (3.9)      | 38.9 - 59.7   | 49.1 (4.2)         | 38.9-57.6   | 51.7 (4.0)         | 41.7-59.7   | 49.9 (3.7)         | 41.5-57.7   | 49.7 (3.7)         | 43.1-57.6   | 48.8 (3.3)         | 43.3-56.9  |
| 40 | Thigh clearance         | 15.8 (1.9)      | 10.9 - 20.9   | 16.0 (1.3)         | 12.9-19.3   | 16.1 (1.8)         | 12.6-20.5   | 15.8 (1.8)         | 12.0-20.9   | 15.6 (1.4)         | 13.1-18.2   | 15.6 (1.7)         | 10.9-19.1  |
| 41 | Buttock-Leg Lgt         | 105.0 (5.4)     | 92.1 – 123.0  | 107.7 (4.4)        | 100.4-123.0 | 106.4 (4.5)        | 95.1-118.8  | 105.0 (5.6)        | 93.6-118.8  | 103.5 (5.2)        | 93.2-115.8  | 102.2 (5.7)        | 92.1-114   |
| 42 | Sit.vertical grip rch   | 122.5 (7.2)     | 94.6 - 139.6  | 127.1 (4.8)        | 116.5-139.6 | 124.8 (5.9)        | 104.0-139.0 | 121.0 (6.8)        | 101.6-132.6 | 120.53 (7.0)       | 104.1-135.9 | 118.5 (7.8)        | 94.6-135.3 |
| 43 | Sit.vertical th-tip rch | 127.4 (7.4)     | 95.6 - 146.5  | 132.1 (5.4)        | 122.5-146.5 | 129.6 (5.7)        | 106.0-138.5 | 126.6 (7.1)        | 106.2-139.7 | 125.0 (7.0)        | 108.0-141.8 | 123.2 (8.2)        | 95.6-140.6 |
| 44 | Sit.vertical fngtip rch | 133.7 (7.4)     | 99.0 - 151.98 | 138.5 (5.1)        | 126.4-152.0 | 135.9 (6.3)        | 114.2-149.4 | 133.0 (6.5)        | 115.4-145.0 | 131.5 (6.9)        | 113.0-144.1 | 129.7 (8.7)        | 99.0-147.5 |
| 45 | Sit.forward grip rch    | 73.4 (5.4)      | 52.2 - 87.4   | 75.2 (4.5)         | 61.5-85.5   | 74.3 (4.8)         | 58.1-82.7   | 73.4 (5.5)         | 56.3-85.2   | 72.3 (5.5)         | 59.1-87.4   | 71.3 (6.2)         | 52.2-82.3  |
| 46 | Sit.forward th-tip rch  | 78.9 (5.6)      | 61.7 - 93.1   | 80.9 (4.8)         | 66.6-93.1   | 80.0 (5.2)         | 61.7-88.9   | 78.6 (5.7)         | 61.7-90.4   | 78.0 (5.3)         | 66.7-91.2   | 76.8 (6.4)         | 63.7-92.1  |

Table 5.1. Anthropometric measurements stratified by age-group (cont'd).

| No | Measurement             | Overall (n=250) |                  | 18-29 years (n=53) |                  | 30-39 years (n=49) |                  | 40-49 years (n=51) |                  | 50-59 years (n=52) |                  | 60-70 years (n=53) |                  |
|----|-------------------------|-----------------|------------------|--------------------|------------------|--------------------|------------------|--------------------|------------------|--------------------|------------------|--------------------|------------------|
|    |                         | $\bar{x}$ (s)   | <i>min – max</i> | $\bar{x}$ (s)      | <i>min – max</i> | $\bar{x}$ (s)      | <i>min – max</i> | $\bar{x}$ (s)      | <i>min – max</i> | $\bar{x}$ (s)      | <i>min – max</i> | $\bar{x}$ (s)      | <i>min – max</i> |
| 47 | Sit.forward fngtip rch  | 84.9 (5.9)      | 66.7 - 97.1      | 86.6 (6.1)         | 67.2-96.6        | 87.0 (5.3)         | 68.0-96.9        | 84.5 (5.2)         | 68.1-96.4        | 83.6 (5.4)         | 71.6-96.0        | 82.7 (6.5)         | 66.7-97.1        |
| 48 | Head circumf            | 56.7 (4.2)      | 50.6 - 62.3      | 57.7 (1.9)         | 50.6-62.3        | 56.8 (1.9)         | 52.6-60.2        | 56.4 (2.1)         | 51.5-61.2        | 56.4 (2.2)         | 51.8-61.0        | 56.2 (2.1)         | 52.8-60.8        |
| 49 | Head lgt                | 18.8 (1.6)      | 14.4 – 22.0      | 19.2 (1.0)         | 16.3-22.0        | 19.0 (0.8)         | 17.3-20.8        | 18.6 (1.0)         | 16.1-21.7        | 18.4 (1.1)         | 14.4-20.4        | 18.7 (0.8)         | 16.2-20.8        |
| 50 | Head brt                | 15.8 (1.3)      | 13.7 - 18.5      | 15.9 (0.7)         | 14.1-18.0        | 15.9 (0.7)         | 14.6-18.5        | 15.9 (0.7)         | 14.5-17.4        | 15.9 (0.8)         | 14.2-17.3        | 15.5 (0.9)         | 13.7-17.4        |
| 51 | Ment-sellion (face) lgt | 12.3 (1.1)      | 10.0 - 14.6      | 12.3 (0.7)         | 10.2-13.9        | 12.3 (0.9)         | 10.0-14.1        | 12.4 (1.0)         | 10.2-14.6        | 12.4 (0.7)         | 10.3-13.7        | 12.2 (0.8)         | 10.5-13.4        |
| 52 | Bizygomatic (face) brt  | 13.0 (1.2)      | 10.6 – 17.0      | 13.0 (1.2)         | 11.5-17.0        | 13.3 (0.8)         | 11.1-15.0        | 13.2 (1.0)         | 11.5-16.3        | 12.9 (0.7)         | 11.2-14.6        | 12.8 (0.9)         | 10.6-15.1        |
| 53 | Neck circumf            | 38.2 (3.8)      | 30.0 - 47.4      | 37.8 (2.8)         | 30.0-44.4        | 38.4 (2.7)         | 33.9-43.3        | 38.4 (3.1)         | 32.6-44.5        | 38.5 (3.4)         | 32.2-47.4        | 38.2 (2.9)         | 30.5-43.2        |
| 54 | Chest circumf           | 96.1 (10.1)     | 80.0- 121.5      | 95.4 (6.8)         | 83.2-118.8       | 95.7 (9.5)         | 81.3-121.5       | 96.6 (8.9)         | 80.0-118.0       | 96.3 (7.2)         | 80.8-118.6       | 96.4 (8.0)         | 85.1-117.9       |
| 55 | Waist circumf           | 90.4 (12.0)     | 64 - 122.4       | 85.5 (8.8)         | 71.2-111.9       | 90.7 (10.8)        | 69.7-122.4       | 91.4 (10.0)        | 73.2-112.0       | 91.7 (11.4)        | 64-115.5         | 93.0 (10.4)        | 65.8-115.0       |
| 56 | Hip brt (sit.)          | 37.8 (3.9)      | 30.2 – 50.0      | 38.6 (3.4)         | 32.2-50.0        | 37.8 (3.0)         | 31.7-48.2        | 37.3 (3.1)         | 30.2-46.7        | 37.6 (2.7)         | 30.4-43.5        | 37.4 (2.9)         | 32.0-45.6        |
| 57 | Sit. e-to-e brt (n)     | 51.4 (6.2)      | 40.2 - 67.2      | 50.5 (4.9)         | 40.5-60.0        | 53.1 (6.0)         | 42.0-67.2        | 51.5 (5.4)         | 41.0-61.0        | 51.7 (4.9)         | 40.2-59.2        | 50.1 (4.8)         | 42.3-60.6        |
| 58 | Shld biacr. brt         | 38.3 (2.2)      | 29.9 - 43.4      | 38.9 (1.9)         | 33.8-42.8        | 39.3 (1.8)         | 35.6-43.2        | 38.1 (2.1)         | 33.1-43.4        | 37.7 (2.3)         | 29.9-41.2        | 37.3 (2.3)         | 32.4-41.1        |
| 59 | Shld bideltoid brt      | 45.8 (3.4)      | 35.9 - 58.7      | 46.0 (2.6)         | 40.0-54.7        | 47.4 (4.0)         | 41.4-58.7        | 45.4 (3.1)         | 38.5-51.5        | 45.3 (3.2)         | 35.9-52.3        | 44.6 (3.3)         | 38.4-52.5        |
| 60 | Hand lgt                | 18.8 (1.7)      | 15.5 - 22.3      | 18.9 (0.9)         | 15.5-20.7        | 18.9 (1.2)         | 17.0-22.3        | 18.9 (1.4)         | 15.6-22.1        | 18.6 (1.3)         | 16.1-22.1        | 18.5 (1.0)         | 16.6-21.4        |
| 61 | Hand brt                | 8.8 (0.8)       | 7.5 - 10.9       | 8.7 (0.7)          | 7.7-10.9         | 8.9 (0.5)          | 8.0-10.1         | 8.8 (0.5)          | 7.5-9.9          | 8.9 (0.5)          | 7.8-10.1         | 8.9 (0.5)          | 7.7-10.1         |
| 62 | Palm lgt perp           | 10.6 (0.9)      | 8.1 - 12.3       | 10.6 (0.8)         | 8.1-11.9         | 10.7 (0.5)         | 9.5-11.7         | 10.8 (0.6)         | 8.8-12.3         | 10.6 (0.6)         | 9.1-11.9         | 10.58 (0.5)        | 9.6-11.7         |
| 63 | Index finger lgt        | 7.3 (0.7)       | 6.1 – 9.0        | 7.3 (0.5)          | 6.2-8.8          | 7.3 (0.5)          | 6.2-8.3          | 7.3 (0.6)          | 6.1-8.3          | 7.3 (0.5)          | 6.1-8.4          | 7.2 (0.6)          | 6.2-9.0          |
| 64 | Hand circumf            | 21.4 (2.2)      | 14.8 - 25.1      | 20.5 (2.1)         | 14.8-24.6        | 21.5 (1.8)         | 15.0-24.8        | 21.4 (1.6)         | 17.4-24.5        | 21.9 (1.3)         | 18.6-24.6        | 21.6 (1.3)         | 18.5-25.1        |
| 65 | Wrist circumf           | 17.8 (2.2)      | 14.0 - 25.7      | 17.1 (1.5)         | 14.8-22.3        | 18.2 (2.2)         | 15.5-25.7        | 18.0 (1.7)         | 15.6-23.1        | 18.3 (2.1)         | 14.0-25.0        | 17.6 (1.6)         | 14.2-22.6        |

Table 5.2. Anthropometric measurements stratified by job-group (all in cm except body mass).

| No | Measurement               | Non-manual workers (n=123) |                 | Manual workers (n=127) |                 |
|----|---------------------------|----------------------------|-----------------|------------------------|-----------------|
|    |                           | $\bar{x}$ (s)              | min – max       | $\bar{x}$ (s)          | min – max       |
| 1  | Body mass (kg)            | 78.92 (13.64)              | 51.00 – 128.00  | 74.35 (11.49)          | 50.00 – 115.00  |
| 2  | Stature (e)               | 172.22 (8.14)              | 153.30 – 189.50 | 170.71 (7.96)          | 154.00 – 189.40 |
| 3  | Stature (n)               | 171.81 (8.08)              | 152.20 – 189.30 | 170.36 (7.83)          | 153.70 – 188.40 |
| 4  | Eye ht (e)                | 161.29 (8.16)              | 142.30 – 178.50 | 160.04 (8.21)          | 142.50 – 180.70 |
| 5  | Eye ht (n)                | 160.88 (8.10)              | 142.00 – 178.30 | 159.69 (8.09)          | 142.50 – 180.50 |
| 6  | Acr. (shld) ht (e)        | 143.30 (7.55)              | 126.70 – 161.70 | 142.30 (7.53)          | 128.00 – 167.40 |
| 7  | Acr. (shld) ht (n)        | 141.57 (7.06)              | 125.90 – 158.50 | 140.87 (7.19)          | 127.30 – 160.60 |
| 8  | Elbow ht (n)              | 106.48 (6.03)              | 94.50 – 120.10  | 105.93 (6.20)          | 92.40 – 125.40  |
| 9  | Fngtip ht (n)             | 63.98 (4.67)               | 53.90 – 78.00   | 63.56 (4.22)           | 52.50 – 73.30   |
| 10 | Th-tip ht (n)             | 69.55 (4.68)               | 58.33 – 81.20   | 68.93 (4.16)           | 58.30 – 77.50   |
| 11 | Knuckle ht (n)            | 75.94 (4.89)               | 63.30– 87.90    | 75.62 (4.79)           | 65.00 – 91.40   |
| 12 | Waist ht (n)              | 101.69 (6.63)              | 79.50 – 119.90  | 103.74 (7.28)          | 67.70 – 120.80  |
| 13 | Vertical grip rch         | 204.13 (11.59)             | 182.20 – 229.10 | 203.61 (10.48)         | 178.00 – 232.90 |
| 14 | Vertical th-tip rch       | 209.12 (11.79)             | 186.5 0- 235.80 | 208.79 (10.8)          | 180.40 – 240.10 |
| 15 | Vertical fngtip rch       | 215.36 (12.06)             | 190.40 – 240.60 | 214.52 (10.88)         | 183.20- 244.60  |
| 16 | Forward grip rch          | 74.29 (4.42)               | 63.70 – 84.50   | 73.98 (4.05)           | 64.52 – 85.50   |
| 17 | Forward th-tip rch        | 80.20 (4.85)               | 71.00 – 91.69   | 79.95 (4.77)           | 68.20 – 95.00   |
| 18 | Forward fngtip rch        | 87.05 (4.77)               | 76.60 – 98.50   | 86.18 (4.85)           | 73.00 – 96.90   |
| 19 | Span                      | 173.5 (8.72)               | 149.80 – 189.30 | 172.58 (8.43)          | 150.50 – 198.20 |
| 20 | Elbow span                | 91.15 (5.34)               | 79.00- 104.40   | 89.62 (4.87)           | 75.80 – 104.70  |
| 21 | Chest (bust) depth        | 22.56 (2.22)               | 17.80 – 29.50   | 22.22 (2.06)           | 16.60 – 28.50   |
| 22 | Chest (bust) brt          | 30.99 (3.23)               | 24.40 – 44.50   | 29.84 (2.42)           | 24.40 – 37.80   |
| 23 | Stand. e-to-e brt         | 51.13 (4.85)               | 41.00 – 65.60   | 50.42 (4.67)           | 40.00 – 66.30   |
| 24 | Shld-elbow lgt            | 36.83 (4.73)               | 20.00 – 53.50   | 36.37 (3.98)           | 24.20 – 52.60   |
| 25 | Shld-fngtip lgt           | 79.33 (5.44)               | 66.30 – 97.60   | 78.74 (5.20)           | 67.50 – 96.50   |
| 26 | Shld-fist (grip axis) lgt | 67.36 (5.94)               | 52.50 – 81.80   | 66.68 (5.33)           | 56.80 – 87.30   |
| 27 | Foot lgt                  | 25.63 (1.47)               | 20.20 – 28.70   | 25.50 (1.56)           | 20.7 0- 29.10   |
| 28 | Foot brt                  | 9.8 (0.76)                 | 8.00- 11.40     | 9.94 (0.78)            | 8.00 – 11.90    |
| 29 | Sit. ht(e)                | 90.97 (3.44)               | 83.60 – 99.80   | 89.46 (4.09)           | 76.60 – 100.90  |
| 30 | Sit. ht (n)               | 90.57 (3.41)               | 83.50 – 99.00   | 89.1 (4.12)            | 76.30 – 99.90   |
| 31 | Sit. eye ht (e)           | 80.47 (3.41)               | 73.5 0- 91.20   | 78.89 (4.3)            | 66.00 – 89.50   |
| 32 | Sit. eye ht (n)           | 80.06 (3.38)               | 73.30 – 90.90   | 78.53 (4.31)           | 65.60 – 89.40   |
| 33 | Sit. acr. (shld) ht (e)   | 62.09 (3.69)               | 54.20 – 82.30   | 61.41 (3.88)           | 50.60 – 78.50   |
| 34 | Sit. acr. (shld) ht (n)   | 60.56 (3.65)               | 52.20 – 77.60   | 60.21 (4.10)           | 49.10 – 79.00   |
| 35 | Sit. elbow rest ht (n)    | 26.12 (2.71)               | 19.40 – 32.70   | 26.67 (3.14)           | 15.50 – 36.50   |
| 36 | Knee ht                   | 51.58 (3.07)               | 45.20 – 59.60   | 51.09 (3.40)           | 44.80 – 68.00   |
| 37 | Popliteal ht              | 42.46 (3.21)               | 34.00 – 50.90   | 41.99 (3.23)           | 33.90 – 56.50   |
| 38 | Buttock-knee lgt          | 60.22 (3.43)               | 52.80 – 67.10   | 59.40 (3.52)           | 47.62 – 67.00   |
| 39 | Buttock-popliteal lgt     | 50.05 (3.83)               | 40.30 – 59.70   | 49.60 (3.98)           | 38.90 – 57.60   |

Table 5.2. Anthropometric measurements stratified by job-group (cont'd).

| No | Measurement             | Non-manual workers (n=123) |                 | Manual workers (n=127) |                |
|----|-------------------------|----------------------------|-----------------|------------------------|----------------|
|    |                         | $\bar{x}$ (s)              | min – max       | $\bar{x}$ (s)          | min – max      |
| 40 | Thigh clearance         | 15.89 (1.43)               | 12.90 - 20.50   | 15.72 (1.74)           | 10.90 - 20.90  |
| 41 | Buttock-Leg Lgt         | 105.32 (5.4)               | 92.10 - 118.80  | 104.74 (5.43)          | 93.60 – 123.00 |
| 42 | Sit.vertical grip rch   | 123.22 (5.9)               | 106.30 - 135.90 | 121.81 (8.16)          | 94.60 - 139.60 |
| 43 | Sit.vertical th-tip rch | 128.28 (5.99)              | 112.00 - 141.80 | 126.56 (8.49)          | 95.60 - 146.50 |
| 44 | Sit.vertical fngtip rch | 134.73 (6.1)               | 119.20 - 147.50 | 132.79 (8.37)          | 99.00 - 151.98 |
| 45 | Sit.forward grip rch    | 74.15 (5.28)               | 52.20 - 87.40   | 72.60 (5.48)           | 55.90 - 85.50  |
| 46 | Sit.forward th-tip rch  | 79.6 (5.42)                | 61.70 - 91.20   | 78.25 (5.72)           | 61.70 - 93.10  |
| 47 | Sit.forward fngtip rch  | 86.06 (5.3)                | 68.00 - 96.40   | 83.85 (6.27)           | 66.70 - 97.10  |
| 48 | Head circumf            | 56.98 (2.04)               | 51.80 - 61.20   | 56.47 (2.12)           | 50.60 - 62.30  |
| 49 | Head lgt                | 18.76 (1.08)               | 14.40 - 21.70   | 18.77 (0.91)           | 16.20 – 22.00  |
| 50 | Head brt                | 15.9 (0.73)                | 14.20 - 17.40   | 15.74 (0.79)           | 13.70 - 18.50  |
| 51 | Ment-sellion (face) lgt | 12.36 (0.79)               | 10.20 - 14.60   | 12.32 (0.84)           | 10.00 - 14.40  |
| 52 | Bizygomatic (face) brt  | 13.08 (0.97)               | 11.50 - 16.30   | 13.01 (0.88)           | 10.6 0– 17.00  |
| 53 | Neck circumf            | 38.69 (3.17)               | 31.70 - 47.40   | 37.81 (2.71)           | 30.00 - 43.50  |
| 54 | Chest circumf           | 97.09 (8.56)               | 80.00 - 121.50  | 95.14 (7.47)           | 81.80 - 118.80 |
| 55 | Waist circumf           | 90.84 (11.10)              | 64.00 - 122.40  | 89.89 (9.99)           | 65.80 – 115.00 |
| 56 | Hip brt (sit.)          | 37.90 (3.14)               | 30.40 - 48.20   | 37.63 (2.96)           | 30.20 – 50.00  |
| 57 | Sit. e-to-e brt (n)     | 52.03 (5.61)               | 40.20 - 67.20   | 50.81 (4.89)           | 40.50 - 63.70  |
| 58 | Shld biacr. brt         | 38.68 (2.11)               | 33.10 – 43.00   | 37.93 (2.18)           | 29.90 - 43.40  |
| 59 | Shld bideltoid brt      | 46.24 (3.55)               | 38.50 - 58.70   | 45.30 (3.12)           | 35.90 - 56.10  |
| 60 | Hand lgt                | 18.84 (1.22)               | 16.10 - 22.10   | 18.71 (1.17)           | 15.50 - 22.30  |
| 61 | Hand brt                | 8.80 (0.59)                | 7.70 - 10.10    | 8.84 (0.53)            | 7.50 - 10.90   |
| 62 | Palm lgt perp           | 10.64 (0.58)               | 8.10 - 12.30    | 10.65 (0.61)           | 8.30 - 12.20   |
| 63 | Index finger lgt        | 7.27 (0.52)                | 6.10 - 8.40     | 7.27 (0.55)            | 6.20 – 9.00    |
| 64 | Hand circumf            | 21.47 (1.76)               | 15.20 - 24.80   | 21.29 (1.66)           | 14.80 - 25.10  |
| 65 | Wrist circumf           | 18.04 (2.15)               | 14.00 - 25.70   | 17.66 (1.56)           | 14.20 - 23.20  |

Table 5.3. Anthropometric measurements stratified by BMIP-group except underweight people (all in cm except body mass).

| No | Measurement                 | Normal weight (n= 97) |               | Over weight (n=146) |               |
|----|-----------------------------|-----------------------|---------------|---------------------|---------------|
|    |                             | $\bar{x}$ (s)         | min – max     | $\bar{x}$ (s)       | min – max     |
| 1  | Body mass (kg)              | 67.25 (7.93)          | 50 - 84       | 83.72 (10.56)       | 63 - 128      |
| 2  | Stature (e)                 | 171.71(9.03)          | 153.3 - 189.5 | 170.81 (7.19)       | 155 - 189.4   |
| 3  | Stature (n)                 | 171.31(8.92)          | 152.2 - 189.3 | 170.45 (7.11)       | 154.6 - 188.4 |
| 4  | Eye ht (e)                  | 160.94(9.11)          | 142.3 - 179.5 | 159.92 (7.23)       | 144.3 - 177.5 |
| 5  | Eye ht (n)                  | 160.54 (9)            | 142 - 179.1   | 159.58 (7.15)       | 143.9 - 176.5 |
| 6  | Acr. (shld) ht (e)          | 142.47(7.84)          | 126.7 - 163.2 | 142.64 (7.1)        | 130.2 - 161.7 |
| 7  | Acr. (shld) ht (n)          | 141.1 (7.57)          | 125.9 - 160.6 | 141.02 (6.7)        | 129.3 - 158.8 |
| 8  | Elbow ht (n)                | 105.83(6.15)          | 92.4 - 120.1  | 106.12 (5.88)       | 93.8 - 121.1  |
| 9  | Fngtip ht (n)               | 63.53 (4.35)          | 52.5 - 71     | 63.78 (4.53)        | 53.9 - 78     |
| 10 | Th - tip ht (n)             | 68.97 (4.25)          | 58.3 - 77.3   | 69.33 (4.62)        | 58.326 - 81.2 |
| 11 | Knuckle ht (n)              | 75.7 (4.28)           | 66 - 85       | 75.73 (5.24)        | 63.3 - 91.4   |
| 12 | Waist ht (n)                | 103.37(6.27)          | 90.5 - 119.9  | 102.21 (7.51)       | 67.7 - 120.8  |
| 13 | Vertical grip rch           | 203.98(10.85)         | 181 - 229.1   | 203.15 (10.84)      | 178 - 228.9   |
| 14 | Vertical th - tip rch       | 208.9 (11)            | 186.3 - 234.6 | 208.3 (11.12)       | 180.4 - 235.8 |
| 15 | Vertical fngtip rch         | 215.09(11.2)          | 188.6 - 239.9 | 214.17 (11.3)       | 183.2 - 241   |
| 16 | Forward grip rch            | 73.96 (3.81)          | 64.8 - 83.4   | 74.09 (4.44)        | 63.7 - 84.5   |
| 17 | Forward th - tip rch        | 79.92 (4.69)          | 68.2 - 91.1   | 79.86 (4.74)        | 70.3 - 94.996 |
| 18 | Forward fngtip rch          | 86.41 (4.8)           | 73 - 96.1     | 86.47 (4.76)        | 76.6 - 98.5   |
| 19 | Span                        | 173.33(9.29)          | 149.8 - 189.3 | 172.47 (8.01)       | 150.5 - 198.2 |
| 20 | Elbow span                  | 89.97 (5.12)          | 79 - 101.4    | 90.43 (5.15)        | 75.8 - 104.7  |
| 21 | Chest (bust) depth          | 21.23 (1.82)          | 16.6 - 26     | 23.18 (2.02)        | 18 - 29.5     |
| 22 | Chest (bust) brt            | 28.99 (3.05)          | 24.4 - 44.5   | 31.42 (2.34)        | 25.7 - 38     |
| 23 | Stand. e - to - e brt       | 48.61 (4.68)          | 40 - 59       | 52.39 (4.12)        | 41.6 - 66.3   |
| 24 | Shld - elbow lgt            | 36.63 (4.69)          | 20 - 52.6     | 36.52 (4.19)        | 24.2 - 53.5   |
| 25 | Shld - fngtip lgt           | 78.94 (5.55)          | 66.3 - 96.5   | 78.86 (5.01)        | 68.8 - 97.6   |
| 26 | Shld - fist (grip axis) lgt | 66.77 (5.79)          | 52.5 - 84.5   | 66.91 (5.32)        | 54 - 81.5     |
| 27 | Foot lgt                    | 25.48 (1.51)          | 20.7 - 29.1   | 25.61 (1.51)        | 20.2 - 29     |
| 28 | Foot brt                    | 9.77 (0.7)            | 8.1 - 11.9    | 9.96 (0.81)         | 8 - 11.7      |
| 29 | Sit. ht(e)                  | 90.16 (4)             | 76.6 - 99.8   | 90.22 (3.78)        | 76.7 - 100.9  |
| 30 | Sit. ht (n)                 | 89.77 (4.05)          | 76.3 - 99.3   | 89.86 (3.72)        | 76.3 - 99.9   |
| 31 | Sit. eye ht (e)             | 79.55 (4.14)          | 66.4 - 91.2   | 79.68 (3.83)        | 66 - 89.5     |
| 32 | Sit. eye ht (n)             | 79.16 (4.16)          | 66.1 - 90.9   | 79.32 (3.78)        | 65.6 - 89.4   |
| 33 | Sit. acr. (shld) ht (e)     | 61.09 (3.73)          | 50.6 - 74.2   | 62.18 (3.81)        | 52.7 - 82.3   |
| 34 | Sit. acr. (shld) ht (n)     | 59.92 (3.82)          | 50 - 74.1     | 60.77 (3.89)        | 49.1 - 79     |
| 35 | Sit. elbow rest ht (n)      | 25.53 (2.88)          | 19.4 - 32.9   | 27.07 (2.81)        | 15.5 - 36.5   |
| 36 | Knee ht                     | 51.13 (3.13)          | 44.8 - 59.6   | 51.34 (3.31)        | 45.2 - 68     |
| 37 | Popliteal ht                | 42.39 (3.04)          | 33.9 - 50.9   | 41.99 (3.3)         | 34 - 56.5     |
| 38 | Buttock - knee lgt          | 59.06 (3.48)          | 50.8 - 66.2   | 60.3 (3.44)         | 47.62 - 67.1  |

Table 5.3. Anthropometric measurements stratified by BMIP-group except underweight people (cont'd).

| No | Measurement               | Normal weight (n= 97) |               | Over weight (n=146) |              |
|----|---------------------------|-----------------------|---------------|---------------------|--------------|
|    |                           | $\bar{x}$ (s)         | min – max     | $\bar{x}$ (s)       | min – max    |
| 39 | Buttock - popliteal lgt   | 49.13 (3.73)          | 39.1 - 57.5   | 50.27 (3.89)        | 38.9 - 59.7  |
| 40 | Thigh clearance           | 15.1 (1.47)           | 10.9 - 19.3   | 16.3 (1.48)         | 12.6 - 20.9  |
| 41 | Buttock - Leg Lgt         | 104.66(5.46)          | 93.6 - 118.8  | 105.11 (5.44)       | 92.1 - 123   |
| 42 | Sit.vertical grip rch     | 122.61(6.91)          | 101.6 - 137.8 | 122.2 (7.31)        | 94.6 - 139.6 |
| 43 | Sit.vertical th - tip rch | 127.16 (7.1)          | 106.2 - 145.5 | 127.29 (7.6)        | 95.6 - 146.5 |
| 44 | Sit.vertical fngtip rch   | 133.56(7.43)          | 113 - 149.4   | 133.68 (7.43)       | 99 - 151.98  |
| 45 | Sit.forward grip rch      | 73.27 (5.55)          | 56.3 - 82.7   | 73.21 (5.33)        | 52.2 - 87.4  |
| 46 | Sit.forward th - tip rch  | 78.7 (5.94)           | 61.7 - 92.1   | 78.72 (5.23)        | 63.7 - 91.2  |
| 47 | Sit.forward fngtip rch    | 84.66 (6.23)          | 68 - 97.1     | 84.81 (5.59)        | 66.7 - 96.9  |
| 48 | Head circumf              | 56.27 (2.05)          | 50.6 - 62.3   | 57.01 (2.03)        | 51.8 - 61.2  |
| 49 | Head lgt                  | 18.65 (0.95)          | 15.6 - 21.5   | 18.79 (0.96)        | 14.4 - 21.7  |
| 50 | Head brt                  | 15.68 (0.69)          | 14.1 - 17.4   | 15.9 (0.8)          | 13.7 - 18.5  |
| 51 | Ment - sellion (face) lgt | 12.27 (0.76)          | 10.2 - 14.4   | 12.39 (0.84)        | 10 - 14.6    |
| 52 | Bizygomatic (face) brt    | 12.87 (0.91)          | 10.6 - 15.1   | 13.12 (0.83)        | 11.1 - 16.3  |
| 53 | Neck circumf              | 36.57 (2.57)          | 30 - 44.4     | 39.39 (2.68)        | 31.7 - 47.4  |
| 54 | Chest circumf             | 90.71 (5.95)          | 80 - 118.8    | 99.74 (7.15)        | 82 - 121.5   |
| 55 | Waist circumf             | 82.81 (8.04)          | 64 - 115      | 95.61 (8.72)        | 73.1 - 122.4 |
| 56 | Hip brt (sit.)            | 36.07 (2.39)          | 30.2 - 42.7   | 38.89 (2.81)        | 32.2 - 50    |
| 57 | Sit. e - to - e brt (n)   | 49.1 (4.94)           | 40.2 - 63.7   | 53.06 (4.83)        | 41 - 67.2    |
| 58 | Shld biacr. brt           | 37.68 (2.32)          | 29.9 - 42.2   | 38.73 (1.98)        | 32.4 - 43.4  |
| 59 | Shld bideltoid brt        | 44.45 (3.08)          | 35.9 - 54.7   | 46.73 (3.26)        | 38.4 - 58.7  |
| 60 | Hand lgt                  | 18.63 (1.05)          | 15.5 - 21.5   | 18.85 (1.28)        | 16.1 - 22.3  |
| 61 | Hand brt                  | 8.68 (0.56)           | 7.5 - 10.3    | 8.92 (0.54)         | 7.7 - 10.9   |
| 62 | Palm lgt perp             | 10.56 (0.64)          | 8.1 - 11.7    | 10.71 (0.54)        | 9.5 - 12.3   |
| 63 | Index finger lgt          | 7.2 (0.44)            | 6.2 - 8.8     | 7.32 (0.59)         | 6.1 - 9      |
| 64 | Hand circumf              | 20.92 (1.67)          | 14.8 - 24.8   | 21.78 (1.52)        | 15 - 25.1    |
| 65 | Wrist circumf             | 17.14 (1.64)          | 14 - 23.1     | 18.31 (1.88)        | 15.3 - 25.7  |

### 5.1.2. Percentile Values

The value of a variable below a certain percent of observations fall is called as a percentile. For example, the score of 95<sup>th</sup> percentile shows the value below which 95 % of the observations fall.

The value of a percentile is calculated as given in equation 5.1;

$$\text{the value of } p^{\text{th}} \text{ percentile} = \bar{x} + (Z_p * s) \quad (5.1)$$

In order to explain in detail, we can give an example to find 95<sup>th</sup> percentile for the case of weight with  $\bar{x} = 76.60$  kg and  $s = 12.78$  kg, as following:

$$\begin{aligned} \text{the value of } 95^{\text{th}} \text{ percentile} &= 76.60 + (Z_{0.95} * 12.78) \\ &= 76.60 + (1.645 * 12.78) \\ &= 97.62 \text{ kg} \end{aligned}$$

which means that 95 % of the male weight is below 97.62 kg and only 5 % is above it.

Percentiles including 5<sup>th</sup>, 50<sup>th</sup>, and 95<sup>th</sup> ones with standard deviation values for age-group, job-group and BMIP-group (in which underweight people were excluded since there were only 7 people in this BMIP-group and this is not enough to conclude accurate results) were calculated as given in Table 5.4, Table 5.5 and Table 5.6.

Table 5.4. Percentiles for subjects' anthropometric characteristics stratified by age-group.

|                         | Overall (n=250) |       |       |      | 18-29 yrs (n=53) |       |       |      | 30-39 yrs (n=49) |       |       |      | 40-49 yrs (n=51) |       |       |      | 50-59 yrs (n=52) |       |       |      | 60-70 yrs (n=53) |       |       |      |
|-------------------------|-----------------|-------|-------|------|------------------|-------|-------|------|------------------|-------|-------|------|------------------|-------|-------|------|------------------|-------|-------|------|------------------|-------|-------|------|
| Meas.                   | 5               | 50    | 95    | sd   | 5                | 50    | 95    | sd   | 5                | 50    | 95    | sd   | 5                | 50    | 95    | sd   | 5                | 50    | 95    | sd   | 5                | 50    | 95    | sd   |
| Body Mass (kg)          | 55.5            | 76.6  | 97.6  | 12.8 | 57.8             | 75.5  | 93.3  | 10.8 | 57.9             | 79.9  | 101.9 | 13.4 | 56.0             | 77.8  | 99.6  | 13.2 | 55.1             | 76.8  | 98.5  | 13.2 | 51.7             | 72.8  | 93.9  | 12.8 |
| Stature (e)             | 158.1           | 171.5 | 184.8 | 8.1  | 165.1            | 176.8 | 188.4 | 7.1  | 163.8            | 174.7 | 185.6 | 6.6  | 159.1            | 171.3 | 183.6 | 7.4  | 157.3            | 168.5 | 179.7 | 6.8  | 153.5            | 165.2 | 177.0 | 7.1  |
| Stature (n)             | 157.9           | 171.1 | 184.2 | 8.0  | 164.6            | 176.2 | 187.7 | 7.0  | 163.4            | 174.3 | 185.2 | 6.6  | 158.9            | 171.0 | 183.1 | 7.3  | 157.2            | 168.1 | 179.1 | 6.7  | 153.2            | 165.0 | 176.7 | 7.1  |
| Eye ht (e)              | 147.1           | 160.7 | 174.2 | 8.2  | 153.2            | 165.6 | 178.1 | 7.6  | 153.2            | 164.3 | 175.3 | 6.7  | 148.1            | 160.4 | 172.7 | 7.4  | 146.4            | 157.7 | 169.0 | 6.8  | 142.5            | 154.6 | 166.8 | 7.4  |
| Eye ht (n)              | 146.9           | 160.3 | 173.6 | 8.1  | 152.7            | 165.0 | 177.4 | 7.5  | 152.8            | 163.9 | 174.9 | 6.7  | 148.0            | 160.1 | 172.2 | 7.3  | 146.2            | 157.4 | 168.5 | 6.7  | 142.2            | 154.4 | 166.5 | 7.4  |
| Acr. (shld) ht (e)      | 130.4           | 142.8 | 155.2 | 7.5  | 134.6            | 146.4 | 158.1 | 7.1  | 135.0            | 146.5 | 157.9 | 6.9  | 131.1            | 142.8 | 154.6 | 7.1  | 129.1            | 140.0 | 150.9 | 6.6  | 127.8            | 137.8 | 147.7 | 6.0  |
| Acr. (shld) ht (n)      | 129.5           | 141.2 | 153.0 | 7.1  | 133.2            | 144.3 | 155.3 | 6.7  | 133.9            | 144.9 | 155.9 | 6.7  | 130.0            | 141.1 | 152.2 | 6.7  | 128.5            | 138.6 | 148.7 | 6.1  | 126.8            | 136.8 | 146.8 | 6.1  |
| Elbow ht (n)            | 96.1            | 106.2 | 116.3 | 6.1  | 101.2            | 109.5 | 117.9 | 5.1  | 99.1             | 108.1 | 117.0 | 5.4  | 95.2             | 105.6 | 116.0 | 6.3  | 95.4             | 104.5 | 113.5 | 5.5  | 92.9             | 102.9 | 113.0 | 6.1  |
| Fngtip ht (n)           | 56.4            | 63.8  | 71.1  | 4.4  | 60.1             | 65.8  | 71.5  | 3.5  | 58.6             | 65.4  | 72.1  | 4.1  | 56.5             | 63.5  | 70.4  | 4.2  | 54.9             | 63.0  | 71.0  | 4.9  | 54.6             | 60.9  | 67.3  | 3.9  |
| Th-tip ht (n)           | 61.9            | 69.2  | 76.5  | 4.4  | 65.2             | 71.3  | 77.4  | 3.7  | 62.6             | 70.6  | 78.5  | 4.8  | 62.2             | 68.6  | 74.9  | 3.9  | 60.4             | 68.3  | 76.3  | 4.8  | 61.1             | 67.2  | 73.3  | 3.7  |
| Fist(gr.ax. knck)ht (n) | 67.8            | 75.8  | 83.8  | 4.8  | 71.3             | 77.8  | 84.3  | 3.9  | 69.1             | 77.2  | 85.3  | 4.9  | 68.2             | 75.3  | 82.3  | 4.3  | 65.3             | 74.5  | 83.6  | 5.5  | 66.9             | 73.9  | 81.0  | 4.3  |
| Waist ht (n)            | 91.1            | 102.7 | 114.3 | 7.0  | 94.1             | 103.1 | 112.1 | 5.4  | 93.5             | 105.2 | 116.9 | 7.1  | 91.6             | 102.7 | 113.8 | 6.7  | 89.2             | 101.7 | 114.1 | 7.6  | 88.1             | 100.9 | 113.6 | 7.7  |
| Vertical grip rch       | 185.7           | 203.9 | 222.1 | 11.0 | 196.7            | 210.7 | 224.8 | 8.5  | 193.1            | 208.1 | 223.1 | 9.1  | 184.3            | 203.1 | 221.9 | 11.4 | 182.3            | 199.4 | 216.5 | 10.4 | 181.1            | 197.2 | 213.3 | 9.7  |
| Vertical th-tip rch     | 190.3           | 209.0 | 227.6 | 11.3 | 200.3            | 215.3 | 230.4 | 9.1  | 198.2            | 213.3 | 228.4 | 9.2  | 189.2            | 208.7 | 228.1 | 11.8 | 186.7            | 204.2 | 221.6 | 10.6 | 185.7            | 202.6 | 219.4 | 10.2 |
| Vertical fngtip rch     | 196.0           | 214.9 | 233.8 | 11.5 | 207.6            | 221.9 | 236.3 | 8.7  | 204.1            | 219.2 | 234.4 | 9.2  | 194.9            | 214.2 | 233.5 | 11.7 | 191.9            | 209.9 | 227.8 | 10.9 | 190.7            | 208.7 | 226.8 | 11.0 |
| Forward grip rch        | 67.2            | 74.1  | 81.1  | 4.2  | 67.8             | 75.1  | 82.3  | 4.4  | 67.6             | 74.7  | 81.8  | 4.3  | 67.3             | 74.2  | 81.2  | 4.2  | 67.2             | 74.0  | 80.8  | 4.1  | 66.3             | 72.5  | 78.8  | 3.8  |
| Forward th-tip rch      | 72.2            | 80.1  | 88.0  | 4.8  | 72.6             | 80.9  | 89.2  | 5.1  | 72.6             | 80.5  | 88.4  | 4.8  | 72.9             | 80.5  | 88.2  | 4.6  | 71.9             | 79.8  | 87.8  | 4.8  | 71.1             | 78.5  | 85.8  | 4.4  |
| Forward fngtip rch      | 78.7            | 86.6  | 94.6  | 4.8  | 80.0             | 88.1  | 96.1  | 4.9  | 79.9             | 87.5  | 95.1  | 4.6  | 79.1             | 86.9  | 94.7  | 4.7  | 78.0             | 85.8  | 93.6  | 4.7  | 77.1             | 84.5  | 91.9  | 4.5  |
| Span                    | 158.9           | 173.0 | 187.2 | 8.6  | 164.6            | 177.1 | 189.6 | 7.6  | 166.0            | 176.6 | 187.3 | 6.4  | 160.0            | 173.5 | 187.0 | 8.2  | 157.7            | 170.1 | 182.4 | 7.5  | 152.3            | 167.2 | 182.1 | 9.0  |
| Elbow span              | 81.9            | 90.4  | 98.9  | 5.2  | 84.7             | 91.9  | 99.1  | 4.4  | 85.3             | 92.4  | 99.5  | 4.3  | 81.7             | 90.9  | 100.1 | 5.6  | 80.5             | 88.9  | 97.3  | 5.1  | 79.5             | 87.5  | 95.6  | 4.9  |
| Chest (bust) depth      | 18.2            | 22.4  | 26.6  | 2.6  | 18.8             | 21.9  | 25.0  | 1.9  | 18.7             | 22.6  | 26.6  | 2.4  | 19.2             | 22.1  | 25.1  | 1.8  | 19.1             | 22.7  | 26.3  | 2.2  | 18.7             | 22.7  | 26.7  | 2.4  |
| Chest (bust) brt        | 24.7            | 30.4  | 36.1  | 3.5  | 25.3             | 30.8  | 36.3  | 3.3  | 26.4             | 31.0  | 35.7  | 2.8  | 25.4             | 30.4  | 35.3  | 3.0  | 25.7             | 30.2  | 34.7  | 2.7  | 25.7             | 29.5  | 33.4  | 2.4  |
| Stand. e-to-e brt       | 42.9            | 50.8  | 58.6  | 4.8  | 42.7             | 50.2  | 57.6  | 4.5  | 43.1             | 52.0  | 60.9  | 5.4  | 43.3             | 50.6  | 57.9  | 4.4  | 44.5             | 51.2  | 57.9  | 4.1  | 41.1             | 49.8  | 58.5  | 5.3  |
| Shld-elbow lgt          | 29.4            | 36.6  | 43.8  | 4.4  | 29.2             | 36.8  | 44.5  | 4.6  | 30.5             | 38.4  | 46.3  | 4.8  | 30.9             | 37.2  | 43.6  | 3.8  | 29.7             | 35.6  | 41.4  | 3.6  | 28.1             | 34.9  | 41.7  | 4.1  |

Table 5.4. Percentiles for subjects' anthropometric characteristics stratified by age-group (cont'd).

|                           | Overall (n=250) |       |       |     | 18-29 yrs (n=53) |       |       |     | 30-39 yrs (n=49) |       |       |     | 40-49 yrs (n=51) |       |       |     | 50-59 yrs (n=52) |       |       |     | 60-70 yrs (n=53) |       |       |     |
|---------------------------|-----------------|-------|-------|-----|------------------|-------|-------|-----|------------------|-------|-------|-----|------------------|-------|-------|-----|------------------|-------|-------|-----|------------------|-------|-------|-----|
| Meas.                     | 5               | 50    | 95    | sd  | 5                | 50    | 95    | sd  | 5                | 50    | 95    | sd  | 5                | 50    | 95    | sd  | 5                | 50    | 95    | sd  | 5                | 50    | 95    | sd  |
| Shld-fngtip lgt           | 70.3            | 79.0  | 87.8  | 5.3 | 71.5             | 80.6  | 89.6  | 5.5 | 71.7             | 81.1  | 90.5  | 5.7 | 70.9             | 79.4  | 87.8  | 5.1 | 70.1             | 77.0  | 84.0  | 4.2 | 69.2             | 76.9  | 84.5  | 4.6 |
| Shld-fist (grip axis) lgt | 57.7            | 67.0  | 76.3  | 5.6 | 59.3             | 68.5  | 77.8  | 5.6 | 61.0             | 69.3  | 77.6  | 5.0 | 58.5             | 67.6  | 76.7  | 5.5 | 57.3             | 65.5  | 73.8  | 5.0 | 54.8             | 63.9  | 73.0  | 5.5 |
| Foot lgt                  | 23.1            | 25.6  | 28.1  | 1.5 | 23.0             | 25.7  | 28.5  | 1.7 | 23.4             | 25.9  | 28.3  | 1.5 | 23.0             | 25.6  | 28.2  | 1.6 | 23.5             | 25.5  | 27.4  | 1.2 | 22.6             | 25.1  | 27.7  | 1.5 |
| Foot brt                  | 8.6             | 9.9   | 11.1  | 0.8 | 8.6              | 9.8   | 11.1  | 0.8 | 8.7              | 9.8   | 11.0  | 0.7 | 8.4              | 9.8   | 11.2  | 0.9 | 8.8              | 10.1  | 11.3  | 0.8 | 8.6              | 9.8   | 11.1  | 0.8 |
| Sit. ht(e)                | 83.9            | 90.2  | 96.6  | 3.9 | 85.6             | 92.0  | 98.4  | 3.9 | 84.9             | 91.2  | 97.6  | 3.9 | 84.4             | 90.4  | 96.5  | 3.7 | 83.4             | 88.7  | 94.0  | 3.2 | 82.8             | 88.5  | 94.2  | 3.5 |
| Sit. ht (n)               | 83.5            | 89.8  | 96.2  | 3.9 | 84.7             | 91.4  | 98.2  | 4.1 | 84.4             | 90.8  | 97.2  | 3.9 | 84.2             | 90.1  | 96.0  | 3.6 | 83.1             | 88.4  | 93.6  | 3.2 | 82.5             | 88.2  | 94.0  | 3.5 |
| Sit. eye ht (e)           | 73.1            | 79.7  | 86.2  | 4.0 | 75.4             | 81.6  | 87.7  | 3.7 | 74.0             | 80.5  | 86.9  | 3.9 | 73.5             | 80.0  | 86.5  | 3.9 | 72.6             | 78.2  | 83.7  | 3.4 | 71.8             | 77.9  | 84.0  | 3.7 |
| Sit. eye ht (n)           | 72.8            | 79.3  | 85.8  | 4.0 | 74.5             | 81.0  | 87.5  | 3.9 | 73.6             | 80.1  | 86.5  | 3.9 | 73.3             | 79.7  | 86.1  | 3.9 | 72.4             | 77.8  | 83.3  | 3.3 | 71.5             | 77.6  | 83.8  | 3.7 |
| Sit. acr. (shld) ht (e)   | 55.5            | 61.7  | 68.0  | 3.8 | 55.9             | 63.0  | 70.0  | 4.3 | 55.4             | 62.6  | 69.8  | 4.4 | 56.4             | 61.6  | 66.8  | 3.2 | 55.6             | 61.0  | 66.4  | 3.3 | 55.2             | 60.4  | 65.6  | 3.2 |
| Sit. acr. (shld) ht (n)   | 54.0            | 60.4  | 66.8  | 3.9 | 53.4             | 61.4  | 69.3  | 4.8 | 53.9             | 61.2  | 68.4  | 4.4 | 54.7             | 60.1  | 65.5  | 3.3 | 54.7             | 59.9  | 65.1  | 3.2 | 54.2             | 59.3  | 64.4  | 3.1 |
| Sit. elbow rest ht (n)    | 20.8            | 26.4  | 32.0  | 3.4 | 20.2             | 25.4  | 30.5  | 3.1 | 20.4             | 26.2  | 32.0  | 3.5 | 22.6             | 26.6  | 30.6  | 2.4 | 22.4             | 26.8  | 31.2  | 2.6 | 22.6             | 27.1  | 31.6  | 2.7 |
| Knee ht                   | 46.0            | 51.3  | 56.7  | 3.3 | 48.9             | 53.1  | 57.4  | 2.6 | 48.0             | 52.3  | 56.7  | 2.6 | 44.8             | 51.1  | 57.4  | 3.8 | 45.4             | 50.5  | 55.6  | 3.1 | 45.1             | 49.4  | 53.6  | 2.6 |
| Popliteal ht              | 36.9            | 42.2  | 47.5  | 3.2 | 38.9             | 43.5  | 48.0  | 2.8 | 38.0             | 43.0  | 48.0  | 3.0 | 36.7             | 42.5  | 48.3  | 3.5 | 35.8             | 41.5  | 47.1  | 3.4 | 36.6             | 40.4  | 44.3  | 2.3 |
| Buttock-knee lgt          | 54.0            | 59.8  | 65.6  | 3.5 | 54.7             | 60.2  | 65.6  | 3.3 | 55.6             | 61.5  | 67.5  | 3.6 | 54.1             | 59.4  | 64.7  | 3.2 | 53.9             | 59.3  | 64.7  | 3.3 | 52.8             | 58.5  | 64.3  | 3.5 |
| Buttock-popliteal lgt     | 43.4            | 49.8  | 56.3  | 3.9 | 42.3             | 49.1  | 56.0  | 4.2 | 45.0             | 51.7  | 58.3  | 4.0 | 43.7             | 49.9  | 56.0  | 3.7 | 43.5             | 49.7  | 55.8  | 3.7 | 43.3             | 48.8  | 54.3  | 3.3 |
| Thigh clearance           | 12.7            | 15.8  | 18.9  | 1.9 | 13.8             | 16.0  | 18.2  | 1.3 | 13.2             | 16.1  | 19.0  | 1.8 | 12.9             | 15.8  | 18.6  | 1.8 | 13.3             | 15.6  | 17.9  | 1.4 | 12.7             | 15.6  | 18.4  | 1.7 |
| Buttock-Leg lgt           | 96.1            | 105.0 | 114.0 | 5.4 | 100.5            | 107.7 | 115.0 | 4.4 | 99.0             | 106.4 | 113.7 | 4.5 | 95.8             | 105.0 | 114.2 | 5.6 | 94.9             | 103.5 | 112.1 | 5.2 | 92.8             | 102.2 | 111.5 | 5.7 |
| Sit.vertical grip rch     | 110.7           | 122.5 | 134.3 | 7.2 | 119.2            | 127.1 | 135.1 | 4.8 | 115.1            | 124.8 | 134.6 | 5.9 | 109.8            | 121.0 | 132.2 | 6.8 | 109.0            | 120.5 | 132.0 | 7.0 | 105.7            | 118.5 | 131.3 | 7.8 |
| Sit.vertical th-tip rch   | 115.2           | 127.4 | 139.6 | 7.4 | 123.1            | 132.1 | 141.0 | 5.4 | 120.2            | 129.6 | 139.0 | 5.7 | 114.8            | 126.6 | 138.4 | 7.1 | 113.4            | 125.0 | 136.6 | 7.0 | 109.7            | 123.2 | 136.8 | 8.2 |
| Sit.vertical fngtip rch   | 121.6           | 133.7 | 145.9 | 7.4 | 130.1            | 138.5 | 146.8 | 5.1 | 125.4            | 135.9 | 146.3 | 6.3 | 122.3            | 133.0 | 143.7 | 6.5 | 119.7            | 131.2 | 142.6 | 6.9 | 115.4            | 129.7 | 144.0 | 8.7 |
| Sit.forward grip rch      | 64.4            | 73.4  | 82.3  | 5.4 | 67.7             | 75.2  | 82.6  | 4.5 | 66.5             | 74.3  | 82.2  | 4.8 | 64.4             | 73.4  | 82.4  | 5.5 | 63.3             | 72.3  | 81.4  | 5.5 | 61.1             | 71.3  | 81.6  | 6.2 |
| Sit.forward th-tip rch    | 69.7            | 78.9  | 88.2  | 5.6 | 73.1             | 80.9  | 88.8  | 4.8 | 71.5             | 80.0  | 88.5  | 5.2 | 69.2             | 78.6  | 87.9  | 5.7 | 69.2             | 78.0  | 86.8  | 5.3 | 66.3             | 76.8  | 87.4  | 6.4 |
| Sit.forward fngtip rch    | 75.2            | 84.9  | 94.7  | 5.9 | 76.6             | 86.6  | 96.7  | 6.1 | 78.2             | 87.0  | 95.8  | 5.3 | 75.9             | 84.5  | 93.1  | 5.2 | 74.7             | 83.6  | 92.5  | 5.4 | 71.9             | 82.7  | 93.5  | 6.5 |
| Head circumf              | 49.9            | 56.7  | 63.6  | 4.2 | 54.6             | 57.7  | 60.8  | 1.9 | 53.8             | 56.8  | 59.9  | 1.9 | 52.9             | 56.4  | 59.9  | 2.1 | 52.8             | 56.4  | 60.0  | 2.2 | 52.8             | 56.2  | 59.6  | 2.1 |

Table 5.4. Percentiles for subjects' anthropometric characteristics stratified by age-group (cont'd).

|                         | Overall (n=250) |      |       |      | 18-29 yrs (n=53) |      |       |     | 30-39 yrs (n=49) |      |       |      | 40-49 yrs (n=51) |      |       |      | 50-59 yrs (n=52) |      |       |      | 60-70 yrs (n=53) |      |       |      |
|-------------------------|-----------------|------|-------|------|------------------|------|-------|-----|------------------|------|-------|------|------------------|------|-------|------|------------------|------|-------|------|------------------|------|-------|------|
| Meas.                   | 5               | 50   | 95    | sd   | 5                | 50   | 95    | sd  | 5                | 50   | 95    | sd   | 5                | 50   | 95    | sd   | 5                | 50   | 95    | sd   | 5                | 50   | 95    | sd   |
| Head lgt                | 16.2            | 18.8 | 21.3  | 1.6  | 17.6             | 19.2 | 20.8  | 1.0 | 17.6             | 19.0 | 20.3  | 0.8  | 16.9             | 18.6 | 20.3  | 1.0  | 16.6             | 18.4 | 20.2  | 1.1  | 17.4             | 18.7 | 20.0  | 0.8  |
| Head brt                | 13.7            | 15.8 | 17.9  | 1.3  | 14.8             | 15.9 | 17.1  | 0.7 | 14.6             | 15.9 | 17.1  | 0.7  | 14.7             | 15.9 | 17.0  | 0.7  | 14.6             | 15.9 | 17.1  | 0.8  | 14.1             | 15.5 | 16.9  | 0.9  |
| Ment-sellion (face) lgt | 10.5            | 12.3 | 14.2  | 1.1  | 11.1             | 12.3 | 13.5  | 0.7 | 10.9             | 12.3 | 13.8  | 0.9  | 10.8             | 12.4 | 14.1  | 1.0  | 11.3             | 12.4 | 13.5  | 0.7  | 11.0             | 12.2 | 13.5  | 0.8  |
| Bizygomatic (face) brt  | 11.0            | 13.0 | 15.1  | 1.2  | 11.1             | 13.0 | 14.9  | 1.2 | 11.9             | 13.3 | 14.6  | 0.8  | 11.6             | 13.2 | 14.8  | 1.0  | 11.7             | 12.9 | 14.1  | 0.7  | 11.4             | 12.8 | 14.3  | 0.9  |
| Neck circumf            | 31.9            | 38.2 | 44.6  | 3.8  | 33.2             | 37.8 | 42.3  | 2.8 | 33.9             | 38.4 | 42.9  | 2.7  | 33.3             | 38.4 | 43.4  | 3.1  | 32.9             | 38.5 | 44.1  | 3.4  | 33.4             | 38.2 | 42.9  | 2.9  |
| Chest circumf           | 79.5            | 96.1 | 112.7 | 10.1 | 84.3             | 95.4 | 106.6 | 6.8 | 80.0             | 95.7 | 111.5 | 9.5  | 82.0             | 96.6 | 111.3 | 8.9  | 84.5             | 96.3 | 108.2 | 7.2  | 83.2             | 96.4 | 109.6 | 8.0  |
| Waist circumf           | 70.6            | 90.4 | 110.1 | 12.0 | 71.0             | 85.5 | 100.1 | 8.8 | 72.9             | 90.7 | 108.5 | 10.8 | 74.9             | 91.4 | 107.8 | 10.0 | 72.9             | 91.7 | 110.5 | 11.4 | 75.9             | 93.0 | 110.0 | 10.4 |
| Hip brt (sit.)          | 31.4            | 37.8 | 44.1  | 3.9  | 33.0             | 38.6 | 44.3  | 3.4 | 32.9             | 37.8 | 42.8  | 3.0  | 32.1             | 37.3 | 42.4  | 3.1  | 33.3             | 37.6 | 42.0  | 2.7  | 32.6             | 37.4 | 42.2  | 2.9  |
| Sit. e-to-e brt (n)     | 41.2            | 51.4 | 61.6  | 6.2  | 42.4             | 50.5 | 58.6  | 4.9 | 43.3             | 53.1 | 63.0  | 6.0  | 42.6             | 51.5 | 60.5  | 5.4  | 43.5             | 51.7 | 59.8  | 4.9  | 42.2             | 50.1 | 58.1  | 4.8  |
| Shld biacr. brt         | 34.7            | 38.3 | 41.9  | 2.2  | 35.8             | 38.9 | 42.0  | 1.9 | 36.4             | 39.3 | 42.3  | 1.8  | 34.7             | 38.1 | 41.6  | 2.1  | 34.0             | 37.7 | 41.5  | 2.3  | 33.6             | 37.3 | 41.1  | 2.3  |
| Shld bideltoid brt      | 40.2            | 45.8 | 51.3  | 3.4  | 41.7             | 46.0 | 50.3  | 2.6 | 40.8             | 47.4 | 54.1  | 4.0  | 40.3             | 45.4 | 50.4  | 3.1  | 40.0             | 45.3 | 50.6  | 3.2  | 39.3             | 44.6 | 50.0  | 3.3  |
| Hand lgt                | 16.0            | 18.8 | 21.5  | 1.7  | 17.3             | 18.9 | 20.4  | 0.9 | 17.0             | 18.9 | 20.9  | 1.2  | 16.7             | 18.9 | 21.2  | 1.4  | 16.4             | 18.6 | 20.8  | 1.3  | 16.8             | 18.5 | 20.2  | 1.0  |
| Hand brt                | 7.5             | 8.8  | 10.1  | 0.8  | 7.6              | 8.7  | 9.8   | 0.7 | 8.0              | 8.9  | 9.7   | 0.5  | 7.9              | 8.8  | 9.7   | 0.5  | 8.0              | 8.9  | 9.8   | 0.5  | 8.1              | 8.9  | 9.7   | 0.5  |
| Palm lgt perp           | 9.2             | 10.6 | 12.1  | 0.9  | 9.4              | 10.6 | 11.9  | 0.8 | 9.9              | 10.7 | 11.5  | 0.5  | 9.7              | 10.8 | 11.8  | 0.6  | 9.6              | 10.6 | 11.5  | 0.6  | 9.8              | 10.6 | 11.4  | 0.5  |
| Index finger lgt        | 6.1             | 7.3  | 8.4   | 0.7  | 6.5              | 7.3  | 8.2   | 0.5 | 6.4              | 7.3  | 8.1   | 0.5  | 6.3              | 7.3  | 8.2   | 0.6  | 6.4              | 7.3  | 8.2   | 0.5  | 6.3              | 7.2  | 8.2   | 0.6  |
| Hand circumf            | 17.8            | 21.4 | 25.0  | 2.2  | 17.1             | 20.5 | 23.9  | 2.1 | 18.5             | 21.5 | 24.5  | 1.8  | 18.9             | 21.4 | 24.0  | 1.6  | 19.8             | 21.9 | 24.1  | 1.3  | 19.5             | 21.6 | 23.8  | 1.3  |
| Wrist circumf           | 14.2            | 17.8 | 21.5  | 2.2  | 14.7             | 17.1 | 19.5  | 1.5 | 14.6             | 18.2 | 21.8  | 2.2  | 15.1             | 18.0 | 20.9  | 1.7  | 14.7             | 18.3 | 21.8  | 2.1  | 15.0             | 17.6 | 20.3  | 1.6  |

Table 5.5. Percentiles for subjects' anthropometric characteristics stratified by job-group.

|                           | Non-manual workers (n=123) |        |        |       | Manual workers (n=127) |        |        |       |
|---------------------------|----------------------------|--------|--------|-------|------------------------|--------|--------|-------|
| Dimension                 | 5                          | 50     | 95     | sd    | 5                      | 50     | 95     | sd    |
| Body mass (kg)            | 56.41                      | 78.92  | 101.44 | 13.64 | 55.39                  | 74.35  | 93.32  | 11.49 |
| Stature (e)               | 158.78                     | 172.22 | 185.66 | 8.14  | 157.58                 | 170.71 | 183.84 | 7.96  |
| Stature (n)               | 158.48                     | 171.81 | 185.14 | 8.08  | 157.43                 | 170.36 | 183.28 | 7.83  |
| Eye ht (e)                | 147.82                     | 161.29 | 174.76 | 8.16  | 146.49                 | 160.04 | 173.58 | 8.21  |
| Eye ht (n)                | 147.52                     | 160.88 | 174.25 | 8.1   | 146.34                 | 159.69 | 173.04 | 8.09  |
| Acr. (shld) ht (e)        | 130.84                     | 143.3  | 155.76 | 7.55  | 129.87                 | 142.3  | 154.73 | 7.53  |
| Acr. (shld) ht (n)        | 129.93                     | 141.57 | 153.22 | 7.06  | 129.01                 | 140.87 | 152.74 | 7.19  |
| Elbow ht (n)              | 96.53                      | 106.48 | 116.42 | 6.03  | 95.7                   | 105.93 | 116.16 | 6.2   |
| Fngtip ht (n)             | 56.28                      | 63.98  | 71.68  | 4.67  | 56.59                  | 63.56  | 70.53  | 4.22  |
| Th-tip ht (n)             | 61.82                      | 69.55  | 77.28  | 4.68  | 62.06                  | 68.93  | 75.8   | 4.16  |
| Fist(gr.ax, knck)ht (n)   | 67.88                      | 75.94  | 84.01  | 4.89  | 67.72                  | 75.62  | 83.52  | 4.79  |
| Waist ht (n)              | 90.75                      | 101.69 | 112.63 | 6.63  | 91.74                  | 103.74 | 115.75 | 7.28  |
| Vertical grip rch         | 185                        | 204.13 | 223.26 | 11.59 | 186.32                 | 203.61 | 220.91 | 10.48 |
| Vertical th-tip rch       | 189.66                     | 209.12 | 228.58 | 11.79 | 190.97                 | 208.79 | 226.6  | 10.8  |
| Vertical fngtip rch       | 195.45                     | 215.36 | 235.27 | 12.06 | 196.58                 | 214.52 | 232.47 | 10.88 |
| Forward grip rch          | 67                         | 74.29  | 81.57  | 4.42  | 67.31                  | 73.98  | 80.66  | 4.05  |
| Forward th-tip rch        | 72.2                       | 80.2   | 88.2   | 4.85  | 72.09                  | 79.95  | 87.81  | 4.77  |
| Forward fngtip rch        | 79.18                      | 87.05  | 94.91  | 4.77  | 78.17                  | 86.18  | 94.19  | 4.85  |
| Span                      | 159.11                     | 173.5  | 187.89 | 8.72  | 158.67                 | 172.58 | 186.49 | 8.43  |
| Elbow span                | 82.34                      | 91.15  | 99.96  | 5.34  | 81.59                  | 89.62  | 97.64  | 4.87  |
| Chest (bust) depth        | 18.9                       | 22.56  | 26.22  | 2.22  | 18.83                  | 22.22  | 25.62  | 2.06  |
| Chest (bust) brt          | 25.65                      | 30.99  | 36.32  | 3.23  | 25.86                  | 29.84  | 33.83  | 2.42  |
| Stand. e-to-e brt         | 43.12                      | 51.13  | 59.14  | 4.85  | 42.71                  | 50.42  | 58.13  | 4.67  |
| Shld-elbow lgt            | 29.02                      | 36.83  | 44.63  | 4.73  | 29.81                  | 36.37  | 42.94  | 3.98  |
| Shld-fngtip lgt           | 70.35                      | 79.33  | 88.3   | 5.44  | 70.15                  | 78.74  | 87.33  | 5.2   |
| Shld-fist (grip axis) lgt | 57.56                      | 67.36  | 77.15  | 5.94  | 57.88                  | 66.68  | 75.48  | 5.33  |
| Foot lgt                  | 23.22                      | 25.63  | 28.05  | 1.47  | 22.92                  | 25.5   | 28.07  | 1.56  |
| Foot brt                  | 8.54                       | 9.8    | 11.05  | 0.76  | 8.65                   | 9.94   | 11.23  | 0.78  |
| Sit. ht(e)                | 85.3                       | 90.97  | 96.64  | 3.44  | 82.71                  | 89.46  | 96.21  | 4.09  |
| Sit. ht (n)               | 84.94                      | 90.57  | 96.2   | 3.41  | 82.31                  | 89.1   | 95.9   | 4.12  |
| Sit. eye ht (e)           | 74.84                      | 80.47  | 86.1   | 3.41  | 71.79                  | 78.89  | 85.98  | 4.3   |
| Sit. eye ht (n)           | 74.48                      | 80.06  | 85.64  | 3.38  | 71.42                  | 78.53  | 85.63  | 4.31  |
| Sit. acr. (shld) ht (e)   | 56                         | 62.09  | 68.17  | 3.69  | 55.01                  | 61.41  | 67.82  | 3.88  |
| Sit. acr. (shld) ht (n)   | 54.54                      | 60.56  | 66.57  | 3.65  | 53.44                  | 60.21  | 66.98  | 4.1   |
| Sit. elbow rest ht (n)    | 21.64                      | 26.12  | 30.59  | 2.71  | 21.49                  | 26.67  | 31.84  | 3.14  |
| Knee ht                   | 46.51                      | 51.58  | 56.65  | 3.07  | 45.48                  | 51.09  | 56.69  | 3.4   |
| Popliteal ht              | 37.16                      | 42.46  | 47.76  | 3.21  | 36.66                  | 41.99  | 47.33  | 3.23  |
| Buttock-knee lgt          | 54.55                      | 60.22  | 65.88  | 3.43  | 53.59                  | 59.4   | 65.21  | 3.52  |
| Buttock-popliteal lgt     | 43.72                      | 50.05  | 56.38  | 3.83  | 43.03                  | 49.6   | 56.18  | 3.98  |
| Thigh clearance           | 13.53                      | 15.89  | 18.24  | 1.43  | 12.85                  | 15.72  | 18.59  | 1.74  |
| Buttock-Leg Lgt           | 96.42                      | 105.32 | 114.22 | 5.4   | 95.77                  | 104.74 | 113.7  | 5.43  |
| Sit.vertical grip rch     | 113.49                     | 123.22 | 132.96 | 5.9   | 108.34                 | 121.81 | 135.27 | 8.16  |
| Sit.vertical th-tip rch   | 118.39                     | 128.28 | 138.17 | 5.99  | 112.55                 | 126.56 | 140.56 | 8.49  |
| Sit.vertical fngtip rch   | 124.66                     | 134.73 | 144.79 | 6.1   | 118.98                 | 132.79 | 146.6  | 8.37  |
| Sit.forward grip rch      | 65.44                      | 74.15  | 82.86  | 5.28  | 63.56                  | 72.6   | 81.64  | 5.48  |
| Sit.forward th-tip rch    | 70.65                      | 79.6   | 88.55  | 5.42  | 68.8                   | 78.25  | 87.69  | 5.72  |
| Sit.forward fngtip rch    | 77.32                      | 86.06  | 94.8   | 5.3   | 73.51                  | 83.85  | 94.2   | 6.27  |
| Head circumf              | 53.61                      | 56.98  | 60.35  | 2.04  | 52.98                  | 56.47  | 59.96  | 2.12  |
| Head lgt                  | 16.98                      | 18.76  | 20.53  | 1.08  | 17.27                  | 18.77  | 20.27  | 0.91  |
| Head brt                  | 14.69                      | 15.9   | 17.1   | 0.73  | 14.45                  | 15.74  | 17.04  | 0.79  |
| Ment-sellion (face) lgt   | 11.06                      | 12.36  | 13.65  | 0.79  | 10.94                  | 12.32  | 13.7   | 0.84  |
| Bizygomatic (face) brt    | 11.47                      | 13.08  | 14.68  | 0.97  | 11.56                  | 13.01  | 14.46  | 0.88  |
| Neck circumf              | 33.46                      | 38.69  | 43.92  | 3.17  | 33.34                  | 37.81  | 42.27  | 2.71  |
| Chest circumf             | 82.98                      | 97.09  | 111.21 | 8.56  | 82.82                  | 95.14  | 107.46 | 7.47  |
| Waist circumf             | 72.52                      | 90.84  | 109.16 | 11.1  | 73.41                  | 89.89  | 106.36 | 9.99  |
| Hip brt (sit.)            | 32.71                      | 37.9   | 43.08  | 3.14  | 32.75                  | 37.63  | 42.5   | 2.96  |
| Sit. e-to-e brt (n)       | 42.77                      | 52.03  | 61.28  | 5.61  | 42.74                  | 50.81  | 58.87  | 4.89  |
| Shld biacr. brt           | 35.19                      | 38.68  | 42.16  | 2.11  | 34.34                  | 37.93  | 41.52  | 2.18  |
| Shld bideltoid brt        | 40.39                      | 46.24  | 52.1   | 3.55  | 40.15                  | 45.3   | 50.44  | 3.12  |
| Hand lgt                  | 16.83                      | 18.84  | 20.85  | 1.22  | 16.78                  | 18.71  | 20.63  | 1.17  |
| Hand brt                  | 7.83                       | 8.8    | 9.78   | 0.59  | 7.96                   | 8.84   | 9.72   | 0.53  |
| Palm lgt perp             | 9.67                       | 10.64  | 11.6   | 0.58  | 9.65                   | 10.65  | 11.66  | 0.61  |
| Index finger lgt          | 6.41                       | 7.27   | 8.13   | 0.52  | 6.36                   | 7.27   | 8.17   | 0.55  |
| Hand circumf              | 18.56                      | 21.47  | 24.38  | 1.76  | 18.55                  | 21.29  | 24.02  | 1.66  |
| Wrist circumf             | 14.48                      | 18.04  | 21.59  | 2.15  | 15.08                  | 17.66  | 20.23  | 1.56  |

Table 5.6. Percentiles for subjects' anthro. characteristics stratified by BMIP-group.

|                           | Normal weight (n= 97) |        |        |       | Over weight (n=146) |        |        |       |
|---------------------------|-----------------------|--------|--------|-------|---------------------|--------|--------|-------|
| Dimension                 | 5                     | 50     | 95     | sd    | 5                   | 50     | 95     | sd    |
| Body mass (kg)            | 54.17                 | 67.25  | 80.33  | 7.93  | 66.30               | 83.72  | 101.15 | 10.56 |
| Stature (e)               | 156.80                | 171.71 | 186.61 | 9.03  | 158.94              | 170.81 | 182.68 | 7.19  |
| Stature (n)               | 156.60                | 171.31 | 186.03 | 8.92  | 158.71              | 170.45 | 182.18 | 7.11  |
| Eye ht (e)                | 145.90                | 160.94 | 175.97 | 9.11  | 147.99              | 159.92 | 171.85 | 7.23  |
| Eye ht (n)                | 145.69                | 160.54 | 175.39 | 9.00  | 147.77              | 159.58 | 171.38 | 7.15  |
| Acr. (shld) ht (e)        | 129.53                | 142.47 | 155.40 | 7.84  | 130.93              | 142.64 | 154.35 | 7.10  |
| Acr. (shld) ht (n)        | 128.62                | 141.10 | 153.58 | 7.57  | 129.97              | 141.02 | 152.08 | 6.70  |
| Elbow ht (n)              | 95.69                 | 105.83 | 115.98 | 6.15  | 96.42               | 106.12 | 115.82 | 5.88  |
| Fngtip ht (n)             | 56.36                 | 63.53  | 70.70  | 4.35  | 56.31               | 63.78  | 71.25  | 4.53  |
| Th-tip ht (n)             | 61.96                 | 68.97  | 75.98  | 4.25  | 61.71               | 69.33  | 76.95  | 4.62  |
| Fist(gr.ax, knck)ht (n)   | 68.63                 | 75.70  | 82.77  | 4.28  | 67.08               | 75.73  | 84.39  | 5.24  |
| Waist ht (n)              | 93.03                 | 103.37 | 113.71 | 6.27  | 89.82               | 102.21 | 114.60 | 7.51  |
| Vertical grip rch         | 186.08                | 203.98 | 221.89 | 10.85 | 185.26              | 203.15 | 221.05 | 10.84 |
| Vertical th-tip rch       | 190.75                | 208.90 | 227.05 | 11.00 | 189.96              | 208.30 | 226.65 | 11.12 |
| Vertical fngtip rch       | 196.61                | 215.09 | 233.57 | 11.20 | 195.51              | 214.17 | 232.82 | 11.30 |
| Forward grip rch          | 67.67                 | 73.96  | 80.25  | 3.81  | 66.77               | 74.09  | 81.41  | 4.44  |
| Forward th-tip rch        | 72.19                 | 79.92  | 87.65  | 4.69  | 72.04               | 79.86  | 87.68  | 4.74  |
| Forward fngtip rch        | 78.48                 | 86.41  | 94.33  | 4.80  | 78.61               | 86.47  | 94.33  | 4.76  |
| Span                      | 158.00                | 173.33 | 188.66 | 9.29  | 159.25              | 172.47 | 185.68 | 8.01  |
| Elbow span                | 81.52                 | 89.97  | 98.41  | 5.12  | 81.93               | 90.43  | 98.93  | 5.15  |
| Chest (bust) depth        | 18.23                 | 21.23  | 24.24  | 1.82  | 19.85               | 23.18  | 26.51  | 2.02  |
| Chest (bust) brt          | 23.96                 | 28.99  | 34.03  | 3.05  | 27.56               | 31.42  | 35.27  | 2.34  |
| Stand. e-to-e brt         | 40.88                 | 48.61  | 56.34  | 4.68  | 45.60               | 52.39  | 59.18  | 4.12  |
| Shld-elbow lgt            | 28.89                 | 36.63  | 44.38  | 4.69  | 29.61               | 36.52  | 43.43  | 4.19  |
| Shld-fngtip lgt           | 69.79                 | 78.94  | 88.09  | 5.55  | 70.60               | 78.86  | 87.12  | 5.01  |
| Shld-fist (grip axis) lgt | 57.22                 | 66.77  | 76.32  | 5.79  | 58.13               | 66.91  | 75.69  | 5.32  |
| Foot lgt                  | 22.99                 | 25.48  | 27.98  | 1.51  | 23.11               | 25.61  | 28.10  | 1.51  |
| Foot brt                  | 8.61                  | 9.77   | 10.93  | 0.70  | 8.62                | 9.96   | 11.29  | 0.81  |
| Sit. ht(e)                | 83.57                 | 90.16  | 96.76  | 4.00  | 83.98               | 90.22  | 96.46  | 3.78  |
| Sit. ht (n)               | 83.08                 | 89.77  | 96.45  | 4.05  | 83.72               | 89.86  | 96.00  | 3.72  |
| Sit. eye ht (e)           | 72.72                 | 79.55  | 86.37  | 4.14  | 73.35               | 79.68  | 86.00  | 3.83  |
| Sit. eye ht (n)           | 72.29                 | 79.16  | 86.02  | 4.16  | 73.08               | 79.32  | 85.56  | 3.78  |
| Sit. acr. (shld) ht (e)   | 54.93                 | 61.09  | 67.25  | 3.73  | 55.90               | 62.18  | 68.47  | 3.81  |
| Sit. acr. (shld) ht (n)   | 53.61                 | 59.92  | 66.23  | 3.82  | 54.35               | 60.77  | 67.19  | 3.89  |
| Sit. elbow rest ht (n)    | 20.78                 | 25.53  | 30.27  | 2.88  | 22.44               | 27.07  | 31.71  | 2.81  |
| Knee ht                   | 45.96                 | 51.13  | 56.30  | 3.13  | 45.88               | 51.34  | 56.79  | 3.31  |
| Popliteal ht              | 37.38                 | 42.39  | 47.40  | 3.04  | 36.55               | 41.99  | 47.44  | 3.30  |
| Buttock-knee lgt          | 53.31                 | 59.06  | 64.80  | 3.48  | 54.63               | 60.30  | 65.97  | 3.44  |
| Buttock-popliteal lgt     | 42.98                 | 49.13  | 55.29  | 3.73  | 43.85               | 50.27  | 56.68  | 3.89  |
| Thigh clearance           | 12.67                 | 15.10  | 17.53  | 1.47  | 13.85               | 16.30  | 18.75  | 1.48  |
| Buttock-Leg Lgt           | 95.64                 | 104.66 | 113.67 | 5.46  | 96.13               | 105.11 | 114.09 | 5.44  |
| Sit.vertical grip rch     | 111.22                | 122.61 | 134.01 | 6.91  | 110.14              | 122.20 | 134.27 | 7.31  |
| Sit.vertical th-tip rch   | 115.44                | 127.16 | 138.88 | 7.10  | 114.76              | 127.29 | 139.83 | 7.60  |
| Sit.vertical fngtip rch   | 121.31                | 133.56 | 145.81 | 7.43  | 121.43              | 133.68 | 145.93 | 7.43  |
| Sit.forward grip rch      | 64.11                 | 73.27  | 82.43  | 5.55  | 64.42               | 73.21  | 82.00  | 5.33  |
| Sit.forward th-tip rch    | 68.89                 | 78.70  | 88.51  | 5.94  | 70.09               | 78.72  | 87.34  | 5.23  |
| Sit.forward fngtip rch    | 74.38                 | 84.66  | 94.93  | 6.23  | 75.59               | 84.81  | 94.03  | 5.59  |
| Head circumf              | 52.89                 | 56.27  | 59.65  | 2.05  | 53.65               | 57.01  | 60.36  | 2.03  |
| Head lgt                  | 17.08                 | 18.65  | 20.23  | 0.95  | 17.21               | 18.79  | 20.36  | 0.96  |
| Head brt                  | 14.55                 | 15.68  | 16.82  | 0.69  | 14.58               | 15.90  | 17.23  | 0.80  |
| Ment-sellion (face) lgt   | 11.02                 | 12.27  | 13.53  | 0.76  | 11.00               | 12.39  | 13.77  | 0.84  |
| Bizygomatic (face) brt    | 11.37                 | 12.87  | 14.36  | 0.91  | 11.74               | 13.12  | 14.49  | 0.83  |
| Neck circumf              | 32.33                 | 36.57  | 40.81  | 2.57  | 34.97               | 39.39  | 43.81  | 2.68  |
| Chest circumf             | 80.89                 | 90.71  | 100.53 | 5.95  | 87.95               | 99.74  | 111.54 | 7.15  |
| Waist circumf             | 69.55                 | 82.81  | 96.08  | 8.04  | 81.23               | 95.61  | 110.00 | 8.72  |
| Hip brt (sit.)            | 32.14                 | 36.07  | 40.01  | 2.39  | 34.26               | 38.89  | 43.53  | 2.81  |
| Sit. e-to-e brt (n)       | 40.94                 | 49.10  | 57.25  | 4.94  | 45.09               | 53.06  | 61.03  | 4.83  |
| Shld biacr. brt           | 33.85                 | 37.68  | 41.51  | 2.32  | 35.46               | 38.73  | 42.00  | 1.98  |
| Shld bideltoid brt        | 39.36                 | 44.45  | 49.54  | 3.08  | 41.34               | 46.73  | 52.11  | 3.26  |
| Hand lgt                  | 16.89                 | 18.63  | 20.37  | 1.05  | 16.74               | 18.85  | 20.96  | 1.28  |
| Hand brt                  | 7.76                  | 8.68   | 9.61   | 0.56  | 8.03                | 8.92   | 9.81   | 0.54  |
| Palm lgt perp             | 9.50                  | 10.56  | 11.61  | 0.64  | 9.81                | 10.71  | 11.61  | 0.54  |
| Index finger lgt          | 6.47                  | 7.20   | 7.93   | 0.44  | 6.35                | 7.32   | 8.28   | 0.59  |
| Hand circumf              | 18.16                 | 20.92  | 23.68  | 1.67  | 19.28               | 21.78  | 24.28  | 1.52  |
| Wrist circumf             | 14.44                 | 17.14  | 19.85  | 1.64  | 15.21               | 18.31  | 21.41  | 1.88  |

### 5.1.3. Box-plots stratified by Independent Factors

**5.1.3.1. Age-Group.** Figure 5.1 shows the box-plots of subjects' body mass according to age groups. It is seen from the figure that body mass increases up to group (30-39) and then decreases.

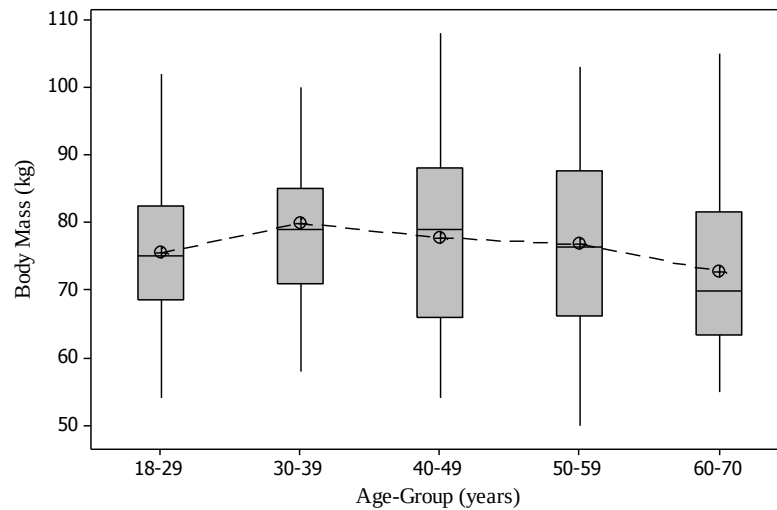


Figure 5.1. Box-plots of body mass of subjects stratified by age-group.

Figure 5.2 shows the box-plots of subjects' stature in normal position according to age groups. It is seen from the figure that stature decreases with increasing age.

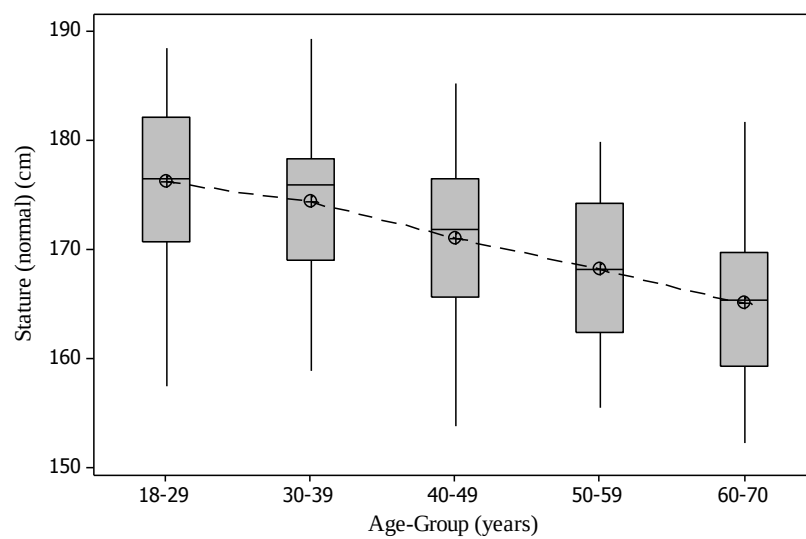


Figure 5.2. Box-plots of stature in normal position of subjects stratified by age-group.

5.1.3.2. Job-Group. Figure 5.3 shows the box-plots of body mass according to occupation groups. According to the figure, non-manual workers are heavier than manual workers. It is seen from Figure 5.4 and Figure 5.5 that there are differences in stature and sitting height between groups. The higher group is non-manual workers for both dimensions.

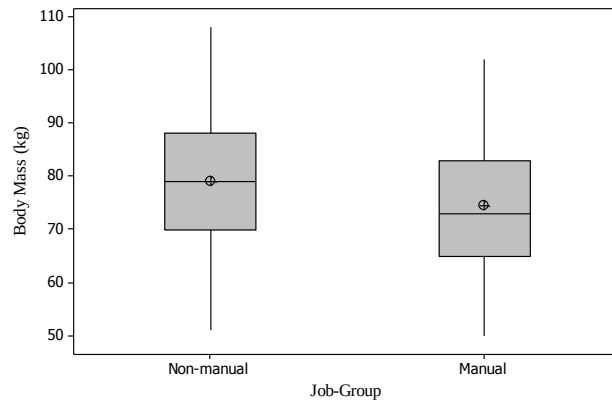


Figure 5.3. Box-plots of body mass of subjects stratified by job-group.

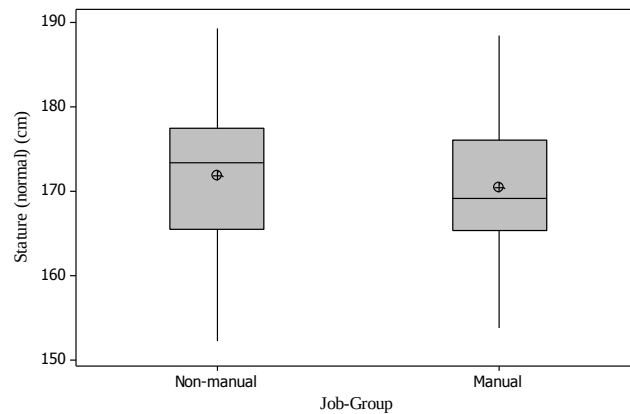


Figure 5.4. Box-plots of stature in normal position of subjects stratified by job-group.

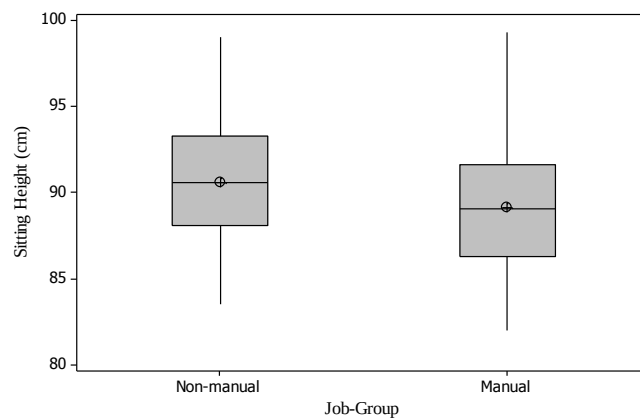


Figure 5.5. Box-plots of sitting height of subjects stratified by job-group.

5.1.3.3. BMIP-Group. Underweight people were excluded from the analyses of BMIP-group effect on the anthropometric measurements since there were only seven subjects in this study and it is not sufficient to generalize the results of this group. Figure 5.6 shows the result of BMIP-group effect on chest circumference. Also, in Figure 5.7, it is shown the effect of BMIP-group on waist circumference.

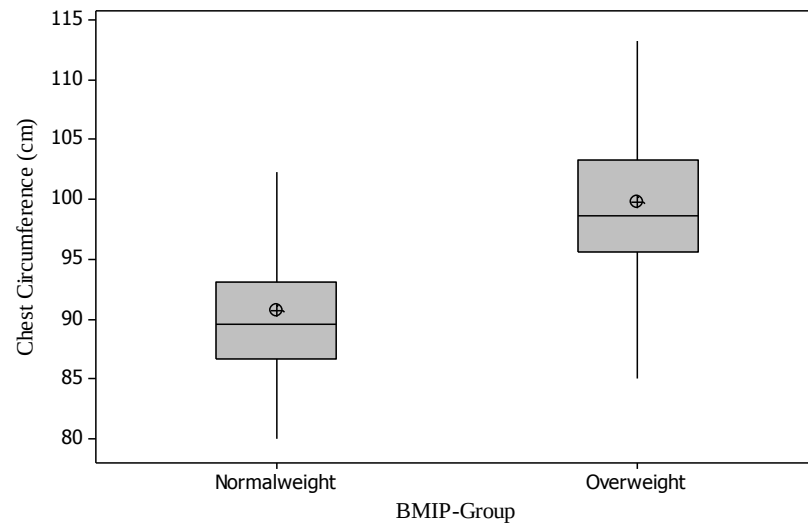


Figure 5.6. Box-plots of chest circumference of subjects stratified by BMIP-group (excluded underweight people).

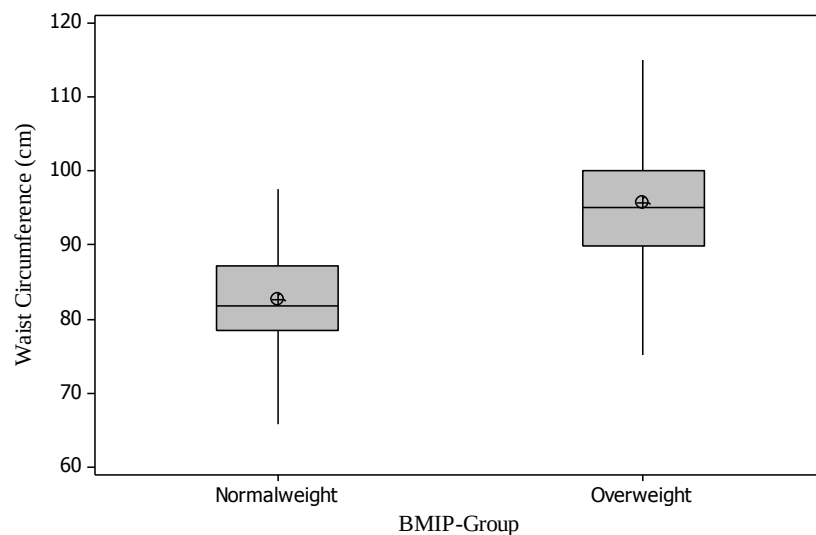


Figure 5.7. Box-plots of waist circumference of subjects stratified by BMIP-group (excluded underweight people).

#### 5.1.4. Distributions of Anthropometric Measurements

Figure 5.8 shows distributions for some anthropometric measurements including body mass, stature, sitting height, waist circumference, hand and foot length in which all of them have skewed normal distributions.

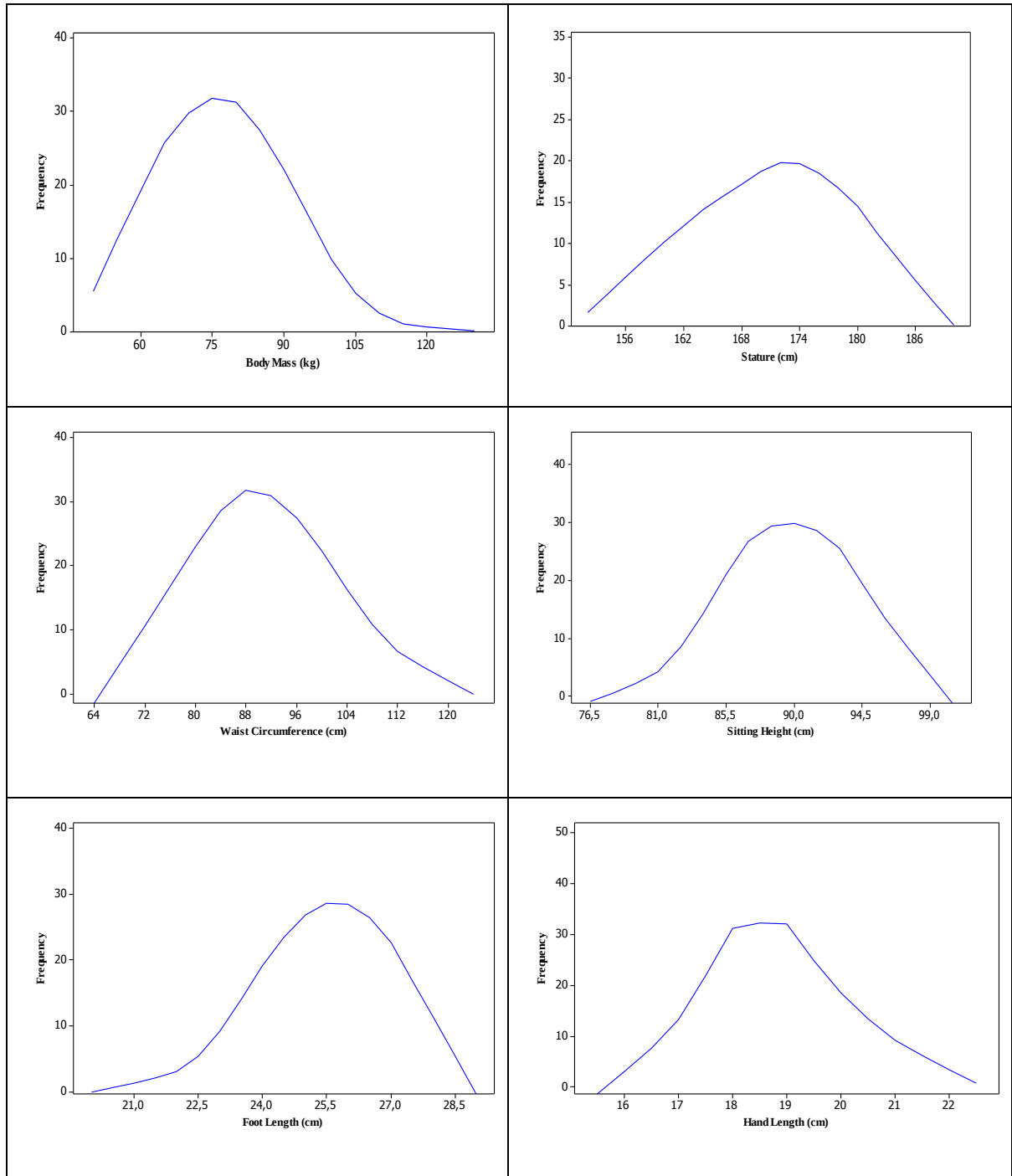


Figure 5.8. Distributions of some anthropometric measurements.

## 5.2. Inferential Statistics

### 5.2.1. Paired T-Test Comparisons

In this study, by using paired t-test, we have tested if mean differences of erect and normal anthropometric measurements are significant. In these tests, the level of significance ( $\alpha$ ) was accepted as 0.05, and values between 0.05 and 0.1 were accepted as marginal significant.

$$\begin{aligned} H_0: \mu_{\text{difference}} &= 0 \\ H_1: \mu_{\text{difference}} &> 0 \end{aligned} \quad (5.2)$$

where  $\mu_{\text{difference}} = \mu_{\text{erect}} - \mu_{\text{normal}}$  is the difference of the mean between two groups. By using the equations of paired t-test formulas which are given in the chapter of methods for all dimensions measured in both erect and normal positions, Table 5.7 is obtained;

Table 5.7. Paired t-test table for eye ht and shoulder ht postures (erect versus normal).

|                                  | $\bar{x}_{\text{erect}}$ | $\bar{x}_{\text{normal}}$ | $\bar{x}_{\text{diff}}$ | $s_{\text{diff}}$ | $t \text{ value}$ | $p \text{ value}$ | Significance Status |
|----------------------------------|--------------------------|---------------------------|-------------------------|-------------------|-------------------|-------------------|---------------------|
| <b>Stature</b>                   | 171.45                   | 171.07                    | 0.38                    | 0.44              | 13.62             | < 0.001           | Significant         |
| <b>Sitting height</b>            | 90.20                    | 89.82                     | 0.38                    | 0.44              | 13.62             | < 0.001           | Significant         |
| <b>Eye height</b>                | 160.66                   | 160.28                    | 0.38                    | 0.44              | 13.62             | < 0.001           | Significant         |
| <b>Eye height (sitting)</b>      | 79.66                    | 79.28                     | 0.38                    | 0.44              | 13.62             | < 0.001           | Significant         |
| <b>Shoulder height</b>           | 142.80                   | 141.22                    | 1.58                    | 2.04              | 12.22             | < 0.001           | Significant         |
| <b>Shoulder height (sitting)</b> | 61.74                    | 60.38                     | 1.36                    | 1.15              | 18.73             | < 0.001           | Significant         |

According to the results given in Table 5.7, there are statistically significant differences between erect and normal positions for stature, sitting height, eye height and shoulder height (in both sitting and standing). On the other hand, these differences are practically so small. In other words, increase in sample size causes increase in significance of difference which means that actually, there is not practically difference while there exists statistically significant difference. This means that if a hypothesis is tested at a fixed

significance level  $\alpha$  and even if there is little practical difference between means, a large sample size will always lead to rejection of null hypothesis (Montgomery, 2005).

### 5.2.2. Correlation Matrix

In order to see the linear relations between anthropometric characteristics, Pearson Correlations were calculated as given in Table 5.8.

Also, the correlation coefficients and p-values were obtained for relations between each anthropometric measurements, BMIP and age of the participants as given in Table 5.9. According to the results of Table 5.9, the following items can be summarized:

- BMIP was found significantly and negatively correlated with some anthropometric measurements including almost all vertical measurements.
- There was a significant and positive correlation between BMIP and some other anthropometric measurements such as chest depth and breadth, elbow-to-elbow breadth in both standing and sitting positions, sitting elbow rest height, buttock knee length, thigh clearance, head circumference, head breadth, bizygomatic (face) breadth, some circumferences including chest, neck, waist, wrist and hand, hip breadth while sitting, shoulder biacromial and bideltoid breadth and hand length.
- Age was found significantly and negatively correlated with some anthropometric measurements including all standing postures and reaching positions.
- There exists a high correlation between almost all vertical measurements including stature and reaching positions.
- Stature does not have a correlation with foot breadth, waist circumference and hand breadth.

Table 5.8. Pearson Correlation coefficients between different anthropometric measurements.\*

| Measurement                  | 1                    | 2                     | 3                     | 4                     | 5                    | 6                    | 7                    | 8                    | 9                    | 10                   | 11                   | 12                    | 13                    |
|------------------------------|----------------------|-----------------------|-----------------------|-----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|-----------------------|-----------------------|
| 1.Body mass (kg)             |                      |                       |                       |                       |                      |                      |                      |                      |                      |                      |                      |                       |                       |
| 2.Stature (e)                | 0.418 (<0.001)       |                       |                       |                       |                      |                      |                      |                      |                      |                      |                      |                       |                       |
| 3.Stature (n)                | 0.419 (<0.001)       | 0.999 (<0.001)        |                       |                       |                      |                      |                      |                      |                      |                      |                      |                       |                       |
| 4.Eye ht (e)                 | 0.404 (<0.001)       | 0.981 (<0.001)        | 0.98 (<0.001)         |                       |                      |                      |                      |                      |                      |                      |                      |                       |                       |
| 5.Eye ht (n)                 | 0.405 (<0.001)       | 0.979 (<0.001)        | 0.98 (<0.001)         | 0.999 (<0.001)        |                      |                      |                      |                      |                      |                      |                      |                       |                       |
| 6.Acr. (shld) ht (e)         | 0.421 (<0.001)       | 0.891 (<0.001)        | 0.892 (<0.001)        | 0.89 (<0.001)         | 0.892 (<0.001)       |                      |                      |                      |                      |                      |                      |                       |                       |
| 7.Acr. (shld) ht (n)         | 0.408 (<0.001)       | 0.856 (<0.001)        | 0.86 (<0.001)         | 0.857 (<0.001)        | 0.86 (<0.001)        | 0.963 (<0.001)       |                      |                      |                      |                      |                      |                       |                       |
| 8.Elbow ht (n)               | 0.401 (<0.001)       | 0.78 (<0.001)         | 0.778 (<0.001)        | 0.768 (<0.001)        | 0.767 (<0.001)       | 0.816 (<0.001)       | 0.823 (<0.001)       |                      |                      |                      |                      |                       |                       |
| 9.Fngtip ht (n)              | 0.333 (<0.001)       | 0.618 (<0.001)        | 0.62 (<0.001)         | 0.605 (<0.001)        | 0.608 (<0.001)       | 0.722 (<0.001)       | 0.734 (<0.001)       | 0.763 (<0.001)       |                      |                      |                      |                       |                       |
| 10.Th-tip ht (n)             | 0.332 (<0.001)       | 0.553 (<0.001)        | 0.558 (<0.001)        | 0.542 (<0.001)        | 0.547 (<0.001)       | 0.643 (<0.001)       | 0.693 (<0.001)       | 0.706 (<0.001)       | 0.88 (<0.001)        |                      |                      |                       |                       |
| 11.Fist(gr.ax. knck)ht (n)   | 0.262 (<0.001)       | 0.538 (<0.001)        | 0.542 (<0.001)        | 0.522 (<0.001)        | 0.527 (<0.001)       | 0.665 (<0.001)       | 0.706 (<0.001)       | 0.684 (<0.001)       | 0.848 (<0.001)       | 0.89 (<0.001)        |                      |                       |                       |
| 12.Waist ht (n)              | <b>0.091 (0.15)</b>  | 0.314 (<0.001)        | 0.324 (<0.001)        | 0.299 (<0.001)        | 0.308 (<0.001)       | 0.401 (<0.001)       | 0.476 (<0.001)       | 0.304 (<0.001)       | 0.501 (<0.001)       | 0.601 (<0.001)       | 0.62 (<0.001)        |                       |                       |
| 13.Vertical grip rch         | 0.311 (<0.001)       | 0.753 (<0.001)        | 0.75 (<0.001)         | 0.724 (<0.001)        | 0.721 (<0.001)       | 0.807 (<0.001)       | 0.768 (<0.001)       | 0.723 (<0.001)       | 0.687 (<0.001)       | 0.642 (<0.001)       | 0.654 (<0.001)       | 0.483 (<0.001)        |                       |
| 14.Vertical th-tip rch       | 0.305 (<0.001)       | 0.753 (<0.001)        | 0.749 (<0.001)        | 0.72 (<0.001)         | 0.716 (<0.001)       | 0.806 (<0.001)       | 0.764 (<0.001)       | 0.726 (<0.001)       | 0.673 (<0.001)       | 0.619 (<0.001)       | 0.646 (<0.001)       | 0.456 (<0.001)        | 0.986 (<0.001)        |
| 15.Vertical fngtip rch       | 0.299 (<0.001)       | 0.742 (<0.001)        | 0.738 (<0.001)        | 0.711 (<0.001)        | 0.707 (<0.001)       | 0.791 (<0.001)       | 0.758 (<0.001)       | 0.723 (<0.001)       | 0.66 (<0.001)        | 0.62 (<0.001)        | 0.634 (<0.001)       | 0.449 (<0.001)        | 0.977 (<0.001)        |
| 16. Forward grip rch         | 0.266 (<0.001)       | 0.556 (<0.001)        | 0.557 (<0.001)        | 0.524 (<0.001)        | 0.525 (<0.001)       | 0.566 (<0.001)       | 0.568 (<0.001)       | 0.546 (<0.001)       | 0.479 (<0.001)       | 0.475 (<0.001)       | 0.458 (<0.001)       | 0.386 (<0.001)        | 0.658 (<0.001)        |
| 17.Forward th-tip rch        | 0.205 (0.001)        | 0.553 (<0.001)        | 0.549 (<0.001)        | 0.536 (<0.001)        | 0.532 (<0.001)       | 0.545 (<0.001)       | 0.514 (<0.001)       | 0.518 (<0.001)       | 0.399 (<0.001)       | 0.334 (<0.001)       | 0.341 (<0.001)       | 0.177 (0.005)         | 0.611 (<0.001)        |
| 18.Forward fngtip rch        | 0.268 (<0.001)       | 0.617 (<0.001)        | 0.612 (<0.001)        | 0.598 (<0.001)        | 0.592 (<0.001)       | 0.6 (<0.001)         | 0.578 (<0.001)       | 0.566 (<0.001)       | 0.423 (<0.001)       | 0.386 (<0.001)       | 0.394 (<0.001)       | 0.199 (0.002)         | 0.661 (<0.001)        |
| 19.Span                      | 0.423 (<0.001)       | 0.922 (<0.001)        | 0.921 (<0.001)        | 0.912 (<0.001)        | 0.911 (<0.001)       | 0.843 (<0.001)       | 0.814 (<0.001)       | 0.717 (<0.001)       | 0.519 (<0.001)       | 0.459 (<0.001)       | 0.461 (<0.001)       | 0.307 (<0.001)        | 0.736 (<0.001)        |
| 20.Elbow span                | 0.408 (<0.001)       | 0.754 (<0.001)        | 0.751 (<0.001)        | 0.74 (<0.001)         | 0.737 (<0.001)       | 0.713 (<0.001)       | 0.661 (<0.001)       | 0.577 (<0.001)       | 0.42 (<0.001)        | 0.359 (<0.001)       | 0.357 (<0.001)       | 0.188 (0.003)         | 0.635 (<0.001)        |
| 21.Chest (bust) depth        | 0.578 (<0.001)       | 0.178 (0.005)         | 0.177 (0.005)         | 0.18 (0.005)          | 0.18 (0.004)         | 0.293 (<0.001)       | 0.277 (<0.001)       | 0.261 (<0.001)       | 0.305 (<0.001)       | 0.295 (<0.001)       | 0.317 (<0.001)       | 0.197 (0.002)         | 0.278 (<0.001)        |
| 22.Chest (bust) brt          | 0.651 (<0.001)       | 0.379 (<0.001)        | 0.379 (<0.001)        | 0.372 (<0.001)        | 0.373 (<0.001)       | 0.424 (<0.001)       | 0.357 (<0.001)       | 0.356 (<0.001)       | 0.277 (<0.001)       | 0.178 (0.005)        | 0.205 (0.001)        | <b>-0.111 (0.08)</b>  | 0.284 (<0.001)        |
| 23.Stand. e-to-e brt         | 0.58 (<0.001)        | 0.254 (<0.001)        | 0.259 (<0.001)        | 0.252 (<0.001)        | 0.258 (<0.001)       | 0.307 (<0.001)       | 0.317 (<0.001)       | 0.332 (<0.001)       | 0.288 (<0.001)       | 0.277 (<0.001)       | 0.264 (<0.001)       | 0.151 (0.017)         | 0.178 (0.005)         |
| 24.Shld-elbow lgt            | 0.166 (0.008)        | 0.448 (<0.001)        | 0.454 (<0.001)        | 0.464 (<0.001)        | 0.468 (<0.001)       | 0.587 (<0.001)       | 0.513 (<0.001)       | <b>0.011 (0.867)</b> | 0.179 (0.005)        | 0.125 (0.049)        | 0.193 (0.002)        | 0.268 (<0.001)        | 0.383 (<0.001)        |
| 25.Shld-fngtip lgt           | 0.319 (<0.001)       | 0.748 (<0.001)        | 0.748 (<0.001)        | 0.757 (<0.001)        | 0.757 (<0.001)       | 0.816 (<0.001)       | 0.753 (<0.001)       | 0.52 (<0.001)        | 0.188 (0.003)        | 0.178 (0.005)        | 0.235 (<0.001)       | 0.151 (0.017)         | 0.57 (<0.001)         |
| 26.Shld-fist (grip axis) lgt | 0.339 (<0.001)       | 0.731 (<0.001)        | 0.729 (<0.001)        | 0.744 (<0.001)        | 0.741 (<0.001)       | 0.768 (<0.001)       | 0.683 (<0.001)       | 0.506 (<0.001)       | 0.239 (<0.001)       | <b>0.098 (0.123)</b> | <b>0.033 (0.608)</b> | <b>0.006 (0.931)</b>  | 0.519 (<0.001)        |
| 27.Foot lgt                  | 0.324 (<0.001)       | 0.543 (<0.001)        | 0.549 (<0.001)        | 0.549 (<0.001)        | 0.554 (<0.001)       | 0.507 (<0.001)       | 0.549 (<0.001)       | 0.411 (<0.001)       | 0.289 (<0.001)       | 0.313 (<0.001)       | 0.302 (<0.001)       | 0.314 (<0.001)        | 0.363 (<0.001)        |
| 28.Foot brt                  | <b>0.094 (0.138)</b> | <b>0.005 (0.943)</b>  | <b>0.01 (0.877)</b>   | <b>0.005 (0.935)</b>  | <b>0.01 (0.874)</b>  | <b>0.032 (0.62)</b>  | 0.152 (0.016)        | <b>0.057 (0.372)</b> | 0.171 (0.007)        | 0.297 (<0.001)       | 0.291 (<0.001)       | 0.443 (<0.001)        | <b>0.063 (0.32)</b>   |
| 29.Sit. ht(e)                | 0.323 (<0.001)       | 0.582 (<0.001)        | 0.585 (<0.001)        | 0.568 (<0.001)        | 0.572 (<0.001)       | 0.526 (<0.001)       | 0.577 (<0.001)       | 0.53 (<0.001)        | 0.511 (<0.001)       | 0.527 (<0.001)       | 0.471 (<0.001)       | 0.212 (0.001)         | 0.451 (<0.001)        |
| 30.Sit. ht (n)               | 0.313 (<0.001)       | 0.554 (<0.001)        | 0.563 (<0.001)        | 0.541 (<0.001)        | 0.551 (<0.001)       | 0.508 (<0.001)       | 0.564 (<0.001)       | 0.507 (<0.001)       | 0.5 (<0.001)         | 0.524 (<0.001)       | 0.468 (<0.001)       | 0.225 (<0.001)        | 0.427 (<0.001)        |
| 31.Sit. eye ht (e)           | 0.314 (<0.001)       | 0.609 (<0.001)        | 0.612 (<0.001)        | 0.625 (<0.001)        | 0.628 (<0.001)       | 0.553 (<0.001)       | 0.558 (<0.001)       | 0.496 (<0.001)       | 0.432 (<0.001)       | 0.415 (<0.001)       | 0.388 (<0.001)       | <b>0.111 (0.079)</b>  | 0.388 (<0.001)        |
| 32.Sit. eye ht (n)           | 0.305 (<0.001)       | 0.584 (<0.001)        | 0.592 (<0.001)        | 0.6 (<0.001)          | 0.608 (<0.001)       | 0.536 (<0.001)       | 0.546 (<0.001)       | 0.475 (<0.001)       | 0.422 (<0.001)       | 0.413 (<0.001)       | 0.387 (<0.001)       | <b>0.124 (0.051)</b>  | 0.365 (<0.001)        |
| 33.Sit. acr. (shld) ht (e)   | 0.368 (<0.001)       | 0.484 (<0.001)        | 0.492 (<0.001)        | 0.504 (<0.001)        | 0.513 (<0.001)       | 0.538 (<0.001)       | 0.576 (<0.001)       | 0.494 (<0.001)       | 0.464 (<0.001)       | 0.444 (<0.001)       | 0.447 (<0.001)       | 0.16 (0.011)          | 0.338 (<0.001)        |
| 34.Sit. acr. (shld) ht (n)   | 0.318 (<0.001)       | 0.381 (<0.001)        | 0.392 (<0.001)        | 0.393 (<0.001)        | 0.405 (<0.001)       | 0.43 (<0.001)        | 0.5 (<0.001)         | 0.425 (<0.001)       | 0.426 (<0.001)       | 0.441 (<0.001)       | 0.424 (<0.001)       | 0.227 (<0.001)        | 0.269 (<0.001)        |
| 35.Sit. elbow rest ht (n)    | 0.272 (<0.001)       | <b>-0.085 (0.178)</b> | <b>-0.074 (0.242)</b> | <b>-0.061 (0.338)</b> | <b>-0.048 (0.45)</b> | <b>0.001 (0.991)</b> | <b>0.074 (0.242)</b> | <b>0.051 (0.424)</b> | 0.16 (0.011)         | 0.223 (<0.001)       | 0.238 (<0.001)       | 0.138 (0.029)         | <b>-0.118 (0.062)</b> |
| 36.Knee ht                   | 0.405 (<0.001)       | 0.796 (<0.001)        | 0.791 (<0.001)        | 0.771 (<0.001)        | 0.765 (<0.001)       | 0.762 (<0.001)       | 0.744 (<0.001)       | 0.698 (<0.001)       | 0.565 (<0.001)       | 0.504 (<0.001)       | 0.491 (<0.001)       | 0.32 (<0.001)         | 0.726 (<0.001)        |
| 37.Popliteal ht              | 0.259 (<0.001)       | 0.608 (<0.001)        | 0.604 (<0.001)        | 0.601 (<0.001)        | 0.598 (<0.001)       | 0.583 (<0.001)       | 0.558 (<0.001)       | 0.505 (<0.001)       | 0.414 (<0.001)       | 0.342 (<0.001)       | 0.332 (<0.001)       | 0.221 (<0.001)        | 0.521 (<0.001)        |
| 38.Buttock-knee lgt          | 0.551 (<0.001)       | 0.705 (<0.001)        | 0.71 (<0.001)         | 0.702 (<0.001)        | 0.707 (<0.001)       | 0.689 (<0.001)       | 0.684 (<0.001)       | 0.579 (<0.001)       | 0.461 (<0.001)       | 0.435 (<0.001)       | 0.396 (<0.001)       | 0.228 (<0.001)        | 0.502 (<0.001)        |
| 39.Buttock-popliteal lgt     | 0.384 (<0.001)       | 0.562 (<0.001)        | 0.57 (<0.001)         | 0.578 (<0.001)        | 0.584 (<0.001)       | 0.563 (<0.001)       | 0.513 (<0.001)       | 0.34 (<0.001)        | 0.278 (<0.001)       | 0.207 (0.001)        | 0.219 (<0.001)       | 0.159 (0.012)         | 0.364 (<0.001)        |
| 40.Thigh clearance           | 0.579 (<0.001)       | 0.364 (<0.001)        | 0.365 (<0.001)        | 0.356 (<0.001)        | 0.356 (<0.001)       | 0.381 (<0.001)       | 0.383 (<0.001)       | 0.347 (<0.001)       | 0.311 (<0.001)       | 0.276 (<0.001)       | 0.299 (<0.001)       | 0.19 (0.003)          | 0.271 (<0.001)        |
| 41.Buttock-Leg Lgt           | 0.428 (<0.001)       | 0.715 (<0.001)        | 0.715 (<0.001)        | 0.706 (<0.001)        | 0.707 (<0.001)       | 0.7 (<0.001)         | 0.701 (<0.001)       | 0.637 (<0.001)       | 0.539 (<0.001)       | 0.506 (<0.001)       | 0.485 (<0.001)       | 0.345 (<0.001)        | 0.645 (<0.001)        |
| 42.Sit.vertical grip rch     | 0.298 (<0.001)       | 0.591 (<0.001)        | 0.591 (<0.001)        | 0.581 (<0.001)        | 0.581 (<0.001)       | 0.569 (<0.001)       | 0.549 (<0.001)       | 0.533 (<0.001)       | 0.455 (<0.001)       | 0.45 (<0.001)        | 0.405 (<0.001)       | 0.208 (0.001)         | 0.59 (<0.001)         |
| 43.Sit.vertical th-tip rch   | 0.369 (<0.001)       | 0.647 (<0.001)        | 0.644 (<0.001)        | 0.631 (<0.001)        | 0.629 (<0.001)       | 0.622 (<0.001)       | 0.583 (<0.001)       | 0.59 (<0.001)        | 0.476 (<0.001)       | 0.44 (<0.001)        | 0.415 (<0.001)       | 0.185 (0.003)         | 0.656 (<0.001)        |
| 44.Sit.vertical fngtip rch   | 0.378 (<0.001)       | 0.658 (<0.001)        | 0.657 (<0.001)        | 0.645 (<0.001)        | 0.645 (<0.001)       | 0.617 (<0.001)       | 0.602 (<0.001)       | 0.577 (<0.001)       | 0.474 (<0.001)       | 0.45 (<0.001)        | 0.422 (<0.001)       | 0.218 (0.001)         | 0.616 (<0.001)        |
| 45.Sit.forward grip rch      | 0.259 (<0.001)       | 0.52 (<0.001)         | 0.52 (<0.001)         | 0.502 (<0.001)        | 0.502 (<0.001)       | 0.495 (<0.001)       | 0.462 (<0.001)       | 0.443 (<0.001)       | 0.331 (<0.001)       | 0.294 (<0.001)       | 0.255 (<0.001)       | 0.138 (0.029)         | 0.583 (<0.001)        |
| 46.Sit.forward th-tip rch    | 0.268 (<0.001)       | 0.569 (<0.001)        | 0.564 (<0.001)        | 0.558 (<0.001)        | 0.554 (<0.001)       | 0.537 (<0.001)       | 0.475 (<0.001)       | 0.461 (<0.001)       | 0.317 (<0.001)       | 0.232 (<0.001)       | 0.214 (0.001)        | <b>0.053 (0.406)</b>  | 0.591 (<0.001)        |
| 47.Sit.forward fngtip rch    | 0.307 (<0.001)       | 0.585 (<0.001)        | 0.58 (<0.001)         | 0.584 (<0.001)        | 0.578 (<0.001)       | 0.542 (<0.001)       | 0.484 (<0.001)       | 0.434 (<0.001)       | 0.296 (<0.001)       | 0.258 (<0.001)       | 0.219 (<0.001)       | <b>0.076 (0.23)</b>   | 0.586 (<0.001)        |
| 48.Head circumf              | 0.338 (<0.001)       | 0.362 (<0.001)        | 0.367 (<0.001)        | 0.374 (<0.001)        | 0.38 (<0.001)        | 0.345 (<0.001)       | 0.366 (<0.001)       | 0.325 (<0.001)       | 0.245 (<0.001)       | 0.218 (0.001)        | 0.185 (0.003)        | <b>-0.028 (0.657)</b> | 0.239 (<0.001)        |
| 49.Head lgt                  | 0.143 (0.024)        | 0.289 (<0.001)        | 0.292 (<0.001)        | 0.281 (<0.001)        | 0.285 (<0.001)       | 0.247 (<0.001)       | 0.256 (<0.001)       | 0.226 (<0.001)       | 0.157 (0.013)        | 0.169 (0.007)        | 0.15 (0.018)         | <b>0.123 (0.052)</b>  | 0.307 (<0.001)        |
| 50.Head brt                  | 0.255 (<0.001)       | 0.162 (0.01)          | 0.162 (0.01)          | 0.189 (0.003)         | 0.19 (0.003)         | 0.16 (0.011)         | 0.16 (0.011)         | 0.135 (0.032)        | <b>0.099 (0.12)</b>  | <b>0.099 (0.12)</b>  | <b>0.056 (0.374)</b> | <b>-0.086 (0.173)</b> | <b>0.072 (0.259)</b>  |
| 51.Ment-sellion (face) lgt   | 0.187 (0.003)        | 0.13 (0.04)           | 0.138 (0.029)         | 0.15 (0.018)          | 0.158 (0.012)        | 0.125 (0.048)        | 0.223 (<0.001)       | 0.148 (0.019)        | <b>0.115 (0.07)</b>  | 0.184 (0.003)        | 0.19 (0.003)         | 0.198 (0.002)         | <b>0.014 (0.822)</b>  |
| 52.Bizygomatic (face) brt    | 0.285 (<0.001)       | 0.304 (<0.001)        | 0.305 (<0.001)        | 0.333 (<0.001)        | 0.333 (<0.001)       | 0.315 (<0.001)       | 0.254 (<0.001)       | 0.185 (0.003)        | <b>0.106 (0.095)</b> | <b>0.016 (0.805)</b> | <b>0.05 (0.429)</b>  | <b>0.012 (0.849)</b>  | 0.209 (0.001)         |
| 53.Neck circumf              | 0.625 (<0.001)       | 0.263 (<0.001)        | 0.264 (<0.001)        | 0.292 (<0.001)        | 0.295 (<0.001)       | 0.286 (<0.001)       | 0.271 (<0.001)       | 0.235 (<0.001)       | 0.138 (0.029)        | <b>0.107 (0.09)</b>  | 0.08 (0.21)          | -0.146 (0.021)        | <b>0.094 (0.14)</b>   |
| 54.Chest circumf             | 0.692 (<0.001)       | 0.259 (<0.001)        | 0.254 (<0.001)        | 0.244 (<0.001)        | 0.24 (<0.001)        | 0.345 (<0.001)       | 0.264 (<0.001)       | 0.345 (<0.001)       | 0.276 (<0.001)       | 0.23 (<0.001)        |                      |                       |                       |

Table 5.8. Pearson Correlation coefficients between different anthropometric measurements (cont'd).

| Measurement                  | 14                    | 15                    | 16                   | 17                    | 18                    | 19                   | 20                    | 21                   | 22                    | 23                   | 24                    | 25                    | 26                   |
|------------------------------|-----------------------|-----------------------|----------------------|-----------------------|-----------------------|----------------------|-----------------------|----------------------|-----------------------|----------------------|-----------------------|-----------------------|----------------------|
| 15.Vertical fngtip rch       | 0.986 (<0.001)        |                       |                      |                       |                       |                      |                       |                      |                       |                      |                       |                       |                      |
| 16.Forward grip rch          | 0.662 (<0.001)        | 0.648 (<0.001)        |                      |                       |                       |                      |                       |                      |                       |                      |                       |                       |                      |
| 17.Forward th-tip rch        | 0.627 (<0.001)        | 0.614 (<0.001)        | 0.864 (<0.001)       |                       |                       |                      |                       |                      |                       |                      |                       |                       |                      |
| 18.Forward fngtip rch        | 0.673 (<0.001)        | 0.668 (<0.001)        | 0.831 (<0.001)       | 0.928 (<0.001)        |                       |                      |                       |                      |                       |                      |                       |                       |                      |
| 19.Span                      | 0.743 (<0.001)        | 0.733 (<0.001)        | 0.585 (<0.001)       | 0.594 (<0.001)        | 0.664 (<0.001)        |                      |                       |                      |                       |                      |                       |                       |                      |
| 20.Elbow span                | 0.644 (<0.001)        | 0.631 (<0.001)        | 0.53 (<0.001)        | 0.547 (<0.001)        | 0.595 (<0.001)        | 0.82 (<0.001)        |                       |                      |                       |                      |                       |                       |                      |
| 21.Chest (bust) depth        | 0.286 (<0.001)        | 0.269 (<0.001)        | 0.296 (<0.001)       | 0.236 (<0.001)        | 0.257 (<0.001)        | 0.188 (0.003)        | 0.203 (0.001)         |                      |                       |                      |                       |                       |                      |
| 22.Chest (bust) brt          | 0.299 (<0.001)        | 0.289 (<0.001)        | 0.201 (0.001)        | 0.221 (<0.001)        | 0.255 (<0.001)        | 0.399 (<0.001)       | 0.407 (<0.001)        | 0.53 (<0.001)        |                       |                      |                       |                       |                      |
| 23.Stand. e-to-e brt         | 0.179 (0.005)         | 0.163 (0.01)          | 0.213 (0.001)        | 0.153 (0.015)         | 0.159 (0.012)         | 0.25 (<0.001)        | 0.245 (<0.001)        | 0.469 (<0.001)       | 0.62 (<0.001)         |                      |                       |                       |                      |
| 24.Shld-elbow lgt            | 0.376 (<0.001)        | 0.356 (<0.001)        | 0.214 (0.001)        | 0.217 (0.001)         | 0.246 (<0.001)        | 0.453 (<0.001)       | 0.425 (<0.001)        | 0.14 (0.028)         | 0.235 (<0.001)        | <b>0.067 (0.293)</b> |                       |                       |                      |
| 25.Shld-fngtip lgt           | 0.581 (<0.001)        | 0.571 (<0.001)        | 0.403 (<0.001)       | 0.44 (<0.001)         | 0.498 (<0.001)        | 0.762 (<0.001)       | 0.66 (<0.001)         | 0.16 (0.012)         | 0.371 (<0.001)        | 0.195 (0.002)        | 0.683 (<0.001)        |                       |                      |
| 26.Shld-fist (grip axis) lgt | 0.525 (<0.001)        | 0.515 (<0.001)        | 0.364 (<0.001)       | 0.437 (<0.001)        | 0.466 (<0.001)        | 0.733 (<0.001)       | 0.649 (<0.001)        | <b>0.12 (0.06)</b>   | 0.392 (<0.001)        | 0.185 (0.003)        | 0.62 (<0.001)         | 0.89 (<0.001)         |                      |
| 27.Foot lgt                  | 0.371 (<0.001)        | 0.373 (<0.001)        | 0.392 (<0.001)       | 0.363 (<0.001)        | 0.419 (<0.001)        | 0.57 (<0.001)        | 0.464 (<0.001)        | 0.197 (0.002)        | 0.221 (<0.001)        | 0.223 (<0.001)       | 0.301 (<0.001)        | 0.477 (<0.001)        | 0.419 (<0.001)       |
| 28.Foot brt                  | <b>0.056 (0.374)</b>  | <b>0.063 (0.318)</b>  | <b>0.12 (0.058)</b>  | <b>-0.015 (0.809)</b> | <b>0.015 (0.817)</b>  | <b>0.01 (0.871)</b>  | <b>-0.059 (0.356)</b> | 0.206 (0.001)        | <b>-0.092 (0.146)</b> | 0.126 (0.046)        | <b>-0.025 (0.695)</b> | <b>-0.098 (0.121)</b> | -0.208 (0.001)       |
| 29.Sit. ht(e)                | 0.451 (<0.001)        | 0.456 (<0.001)        | 0.35 (<0.001)        | 0.304 (<0.001)        | 0.364 (<0.001)        | 0.517 (<0.001)       | 0.399 (<0.001)        | <b>0.096 (0.133)</b> | 0.247 (<0.001)        | 0.224 (<0.001)       | 0.168 (0.008)         | 0.32 (<0.001)         | 0.301 (<0.001)       |
| 30.Sit. ht (n)               | 0.424 (<0.001)        | 0.43 (<0.001)         | 0.339 (<0.001)       | 0.281 (<0.001)        | 0.338 (<0.001)        | 0.491 (<0.001)       | 0.375 (<0.001)        | <b>0.09 (0.156)</b>  | 0.237 (<0.001)        | 0.227 (<0.001)       | 0.168 (0.008)         | 0.302 (<0.001)        | 0.278 (<0.001)       |
| 31.Sit. eye ht (e)           | 0.386 (<0.001)        | 0.386 (<0.001)        | 0.248 (<0.001)       | 0.232 (<0.001)        | 0.315 (<0.001)        | 0.549 (<0.001)       | 0.455 (<0.001)        | <b>0.089 (0.163)</b> | 0.317 (<0.001)        | 0.22 (<0.001)        | 0.261 (<0.001)        | 0.424 (<0.001)        | 0.407 (<0.001)       |
| 32.Sit. eye ht (n)           | 0.361 (<0.001)        | 0.361 (<0.001)        | 0.238 (<0.001)       | 0.211 (0.001)         | 0.291 (<0.001)        | 0.525 (<0.001)       | 0.433 (<0.001)        | <b>0.084 (0.188)</b> | 0.308 (<0.001)        | 0.223 (<0.001)       | 0.262 (<0.001)        | 0.408 (<0.001)        | 0.386 (<0.001)       |
| 33.Sit. acr. (shld) ht (e)   | 0.339 (<0.001)        | 0.336 (<0.001)        | 0.151 (0.017)        | 0.152 (0.016)         | 0.224 (<0.001)        | 0.455 (<0.001)       | 0.366 (<0.001)        | 0.191 (0.002)        | 0.337 (<0.001)        | 0.356 (<0.001)       | 0.238 (<0.001)        | 0.375 (<0.001)        | 0.336 (<0.001)       |
| 34.Sit. acr. (shld) ht (n)   | 0.264 (<0.001)        | 0.264 (<0.001)        | 0.127 (0.045)        | <b>0.09 (0.155)</b>   | 0.153 (0.015)         | 0.361 (<0.001)       | 0.26 (<0.001)         | 0.173 (0.006)        | 0.248 (<0.001)        | 0.338 (<0.001)       | 0.15 (0.018)          | 0.254 (<0.001)        | 0.212 (0.001)        |
| 35.Sit. elbow rest ht (n)    | <b>-0.119 (0.059)</b> | -0.131 (0.039)        | <b>-0.091 (0.15)</b> | -0.209 (0.001)        | -0.194 (0.002)        | 0.146 (0.021)        | -0.215 (0.001)        | <b>0.111 (0.081)</b> | 0.353 (<0.001)        | <b>-0.07 (0.27)</b>  | -0.133 (0.036)        | -0.203 (0.001)        |                      |
| 36.Knee ht                   | 0.724 (<0.001)        | 0.716 (<0.001)        | 0.58 (<0.001)        | 0.561 (<0.001)        | 0.597 (<0.001)        | 0.792 (<0.001)       | 0.686 (<0.001)        | 0.228 (<0.001)       | 0.318 (<0.001)        | 0.239 (<0.001)       | 0.34 (<0.001)         | 0.609 (<0.001)        | 0.599 (<0.001)       |
| 37.Popliteal ht              | 0.524 (<0.001)        | 0.516 (<0.001)        | 0.358 (<0.001)       | 0.344 (<0.001)        | 0.366 (<0.001)        | 0.624 (<0.001)       | 0.545 (<0.001)        | <b>0.049 (0.438)</b> | 0.208 (0.001)         | <b>0.076 (0.233)</b> | 0.3 (<0.001)          | 0.48 (<0.001)         | 0.495 (<0.001)       |
| 38.Buttock-knee lgt          | 0.506 (<0.001)        | 0.493 (<0.001)        | 0.476 (<0.001)       | 0.439 (<0.001)        | 0.471 (<0.001)        | 0.695 (<0.001)       | 0.629 (<0.001)        | 0.303 (<0.001)       | 0.408 (<0.001)        | 0.384 (<0.001)       | 0.381 (<0.001)        | 0.593 (<0.001)        | 0.583 (<0.001)       |
| 39.Buttock-popliteal lgt     | 0.369 (<0.001)        | 0.354 (<0.001)        | 0.361 (<0.001)       | 0.354 (<0.001)        | 0.365 (<0.001)        | 0.572 (<0.001)       | 0.584 (<0.001)        | 0.226 (<0.001)       | 0.323 (<0.001)        | 0.215 (0.001)        | 0.497 (<0.001)        | 0.566 (<0.001)        | 0.566 (<0.001)       |
| 40.Thigh clearance           | 0.274 (<0.001)        | 0.266 (<0.001)        | 0.167 (0.008)        | <b>0.085 (0.18)</b>   | 0.148 (0.019)         | 0.371 (<0.001)       | 0.298 (<0.001)        | 0.423 (<0.001)       | 0.391 (<0.001)        | 0.365 (<0.001)       | 0.172 (0.006)         | 0.28 (<0.001)         | 0.253 (<0.001)       |
| 41.Buttock-Leg Lgt           | 0.642 (<0.001)        | 0.641 (<0.001)        | 0.529 (<0.001)       | 0.488 (<0.001)        | 0.568 (<0.001)        | 0.721 (<0.001)       | 0.581 (<0.001)        | 0.257 (<0.001)       | 0.312 (<0.001)        | 0.263 (<0.001)       | 0.319 (<0.001)        | 0.543 (<0.001)        | 0.522 (<0.001)       |
| 42.Sit.vertical grip rch     | 0.577 (<0.001)        | 0.573 (<0.001)        | 0.396 (<0.001)       | 0.39 (<0.001)         | 0.446 (<0.001)        | 0.549 (<0.001)       | 0.481 (<0.001)        | 0.133 (0.036)        | 0.248 (<0.001)        | 0.195 (0.002)        | 0.238 (<0.001)        | 0.427 (<0.001)        | 0.414 (<0.001)       |
| 43.Sit.vertical th-tip rch   | 0.654 (<0.001)        | 0.647 (<0.001)        | 0.454 (<0.001)       | 0.465 (<0.001)        | 0.518 (<0.001)        | 0.623 (<0.001)       | 0.534 (<0.001)        | 0.204 (0.001)        | 0.346 (<0.001)        | 0.272 (<0.001)       | 0.249 (<0.001)        | 0.484 (<0.001)        | 0.476 (<0.001)       |
| 44.Sit.vertical fngtip rch   | 0.608 (<0.001)        | 0.608 (<0.001)        | 0.415 (<0.001)       | 0.396 (<0.001)        | 0.467 (<0.001)        | 0.632 (<0.001)       | 0.519 (<0.001)        | 0.188 (0.003)        | 0.332 (<0.001)        | 0.265 (<0.001)       | 0.259 (<0.001)        | 0.479 (<0.001)        | 0.464 (<0.001)       |
| 45.Sit.forward grip rch      | 0.573 (<0.001)        | 0.583 (<0.001)        | 0.579 (<0.001)       | 0.568 (<0.001)        | 0.585 (<0.001)        | 0.519 (<0.001)       | 0.503 (<0.001)        | 0.19 (0.003)         | 0.246 (<0.001)        | 0.19 (0.002)         | 0.235 (<0.001)        | 0.425 (<0.001)        | 0.443 (<0.001)       |
| 46.Sit.forward th-tip rch    | 0.595 (<0.001)        | 0.598 (<0.001)        | 0.565 (<0.001)       | 0.636 (<0.001)        | 0.642 (<0.001)        | 0.585 (<0.001)       | 0.548 (<0.001)        | 0.199 (0.002)        | 0.3 (<0.001)          | 0.178 (0.005)        | 0.283 (<0.001)        | 0.497 (<0.001)        | 0.535 (<0.001)       |
| 47.Sit.forward fngtip rch    | 0.586 (<0.001)        | 0.595 (<0.001)        | 0.558 (<0.001)       | 0.609 (<0.001)        | 0.655 (<0.001)        | 0.612 (<0.001)       | 0.586 (<0.001)        | 0.192 (0.002)        | 0.308 (<0.001)        | 0.169 (0.007)        | 0.329 (<0.001)        | 0.522 (<0.001)        | 0.537 (<0.001)       |
| 48.Head circumf              | 0.239 (<0.001)        | 0.238 (<0.001)        | 0.136 (0.032)        | 0.15 (0.018)          | 0.204 (0.001)         | 0.331 (<0.001)       | 0.264 (<0.001)        | 0.209 (0.001)        | 0.386 (<0.001)        | 0.325 (<0.001)       | 0.142 (0.025)         | 0.285 (<0.001)        | 0.303 (<0.001)       |
| 49.Head lgt                  | 0.308 (<0.001)        | 0.298 (<0.001)        | 0.223 (<0.001)       | 0.217 (0.001)         | 0.244 (<0.001)        | 0.254 (<0.001)       | 0.17 (0.007)          | <b>0.053 (0.408)</b> | <b>0.107 (0.091)</b>  | <b>0.055 (0.389)</b> | 0.111 (0.08)          | 0.22 (<0.001)         | 0.202 (0.001)        |
| 50.Head brt                  | <b>0.061 (0.334)</b>  | <b>0.064 (0.317)</b>  | <b>0.003 (0.956)</b> | <b>0.022 (0.724)</b>  | <b>0.103 (0.104)</b>  | 0.137 (0.031)        | <b>0.064 (0.313)</b>  | 0.234 (<0.001)       | 0.324 (<0.001)        | 0.264 (<0.001)       | <b>0.088 (0.167)</b>  | 0.145 (0.022)         | 0.166 (0.008)        |
| 51.Ment-sellion (face) lgt   | <b>0.015 (0.816)</b>  | <b>0.013 (0.839)</b>  | <b>0.08 (0.206)</b>  | <b>-0.007 (0.908)</b> | <b>0.069 (0.276)</b>  | 0.142 (0.025)        | <b>0.054 (0.395)</b>  | 0.169 (0.008)        | <b>0.106 (0.095)</b>  | 0.312 (<0.001)       | <b>0.009 (0.889)</b>  | <b>0.082 (0.197)</b>  | <b>0.005 (0.937)</b> |
| 52.Bizygomatic (face) brt    | 0.21 (0.001)          | 0.195 (0.002)         | 0.138 (0.029)        | 0.183 (0.004)         | 0.182 (0.004)         | 0.312 (<0.001)       | 0.324 (<0.001)        | 0.229 (<0.001)       | 0.372 (<0.001)        | 0.189 (0.003)        | 0.285 (<0.001)        | 0.358 (<0.001)        | 0.378 (<0.001)       |
| 53.Neck circumf              | <b>0.102 (0.106)</b>  | <b>0.084 (0.183)</b>  | 0.164 (0.01)         | 0.182 (0.004)         | 0.229 (<0.001)        | 0.283 (<0.001)       | 0.312 (<0.001)        | 0.541 (<0.001)       | 0.647 (<0.001)        | 0.572 (<0.001)       | 0.166 (0.009)         | 0.291 (<0.001)        | 0.315 (<0.001)       |
| 54.Chest circumf             | 0.33 (<0.001)         | 0.317 (<0.001)        | 0.276 (<0.001)       | 0.241 (<0.001)        | 0.259 (<0.001)        | 0.282 (<0.001)       | 0.3 (<0.001)          | 0.703 (<0.001)       | 0.69 (<0.001)         | 0.558 (<0.001)       | <b>0.114 (0.073)</b>  | 0.258 (<0.001)        | 0.272 (<0.001)       |
| 55.Waist circumf             | 0.176 (0.005)         | 0.159 (0.012)         | 0.207 (0.001)        | 0.181 (0.004)         | 0.172 (0.006)         | <b>0.123 (0.052)</b> | 0.175 (0.006)         | 0.735 (<0.001)       | 0.626 (<0.001)        | 0.529 (<0.001)       | <b>0.063 (0.32)</b>   | <b>0.106 (0.094)</b>  | 0.127 (0.044)        |
| 56.Hip brt (sit.)            | 0.323 (<0.001)        | 0.327 (<0.001)        | 0.233 (<0.001)       | 0.135 (0.032)         | 0.14 (0.026)          | 0.238 (<0.001)       | 0.212 (0.001)         | 0.474 (<0.001)       | 0.48 (<0.001)         | 0.422 (<0.001)       | <b>0.042 (0.507)</b>  | 0.174 (0.006)         | 0.18 (0.004)         |
| 57.Sit. e-to-e brt (n)       | <b>0.095 (0.136)</b>  | <b>0.079 (0.213)</b>  | <b>0.095 (0.133)</b> | <b>0.065 (0.309)</b>  | <b>0.107 (0.092)</b>  | 0.289 (<0.001)       | 0.309 (<0.001)        | 0.452 (<0.001)       | 0.633 (<0.001)        | 0.743 (<0.001)       | 0.137 (0.03)          | 0.271 (<0.001)        | 0.287 (<0.001)       |
| 58.Shld biacr. brt           | 0.384 (<0.001)        | 0.396 (<0.001)        | 0.288 (<0.001)       | 0.267 (<0.001)        | 0.365 (<0.001)        | 0.486 (<0.001)       | 0.419 (<0.001)        | 0.245 (<0.001)       | 0.458 (<0.001)        | 0.361 (<0.001)       | 0.184 (0.004)         | 0.348 (<0.001)        | 0.343 (<0.001)       |
| 59.Shld bideltoid brt        | 0.256 (<0.001)        | 0.259 (<0.001)        | 0.278 (<0.001)       | <b>0.208 (0.001)</b>  | 0.269 (<0.001)        | 0.42 (<0.001)        | 0.391 (<0.001)        | 0.416 (<0.001)       | 0.611 (<0.001)        | 0.613 (<0.001)       | 0.164 (0.009)         | 0.311 (<0.001)        | 0.33 (<0.001)        |
| 60.Hand lgt                  | 0.201 (0.001)         | 0.207 (0.001)         | 0.244 (<0.001)       | 0.276 (<0.001)        | 0.334 (<0.001)        | 0.531 (<0.001)       | 0.408 (<0.001)        | <b>0.078 (0.224)</b> | 0.296 (<0.001)        | 0.232 (<0.001)       | 0.303 (<0.001)        | 0.52 (<0.001)         | 0.497 (<0.001)       |
| 61.Hand brt                  | <b>0.043 (0.494)</b>  | <b>0.038 (0.554)</b>  | <b>0.029 (0.644)</b> | <b>-0.008 (0.898)</b> | <b>0.031 (0.629)</b>  | <b>0.048 (0.453)</b> | <b>-0.027 (0.676)</b> | 0.307 (<0.001)       | 0.17 (0.007)          | 0.328 (<0.001)       | <b>0.009 (0.89)</b>   | <b>0.022 (0.724)</b>  | <b>-0.044 (0.49)</b> |
| 62.Palm lgt perp             | 0.311 (<0.001)        | 0.31 (<0.001)         | 0.348 (<0.001)       | 0.292 (<0.001)        | 0.338 (<0.001)        | 0.399 (<0.001)       | 0.257 (<0.001)        | 0.156 (0.014)        | 0.234 (<0.001)        | 0.289 (<0.001)       | 0.198 (0.002)         | 0.321 (<0.001)        | 0.268 (<0.001)       |
| 63.Index finger lgt          | <b>0.079 (0.21)</b>   | <b>0.087 (0.168)</b>  | <b>0.11 (0.083)</b>  | 0.146 (0.021)         | 0.195 (0.002)         | 0.346 (<0.001)       | 0.22 (<0.001)         | <b>0.048 (0.452)</b> | 0.207 (0.001)         | 0.229 (<0.001)       | <b>0.089 (0.161)</b>  | 0.33 (<0.001)         | 0.326 (<0.001)       |
| 64.Hand circumf              | -0.145 (0.022)        | -0.151 (0.017)        | <b>-0.022 (0.73)</b> | <b>-0.069 (0.279)</b> | <b>-0.053 (0.402)</b> | <b>0.117 (0.065)</b> | <b>0.056 (0.375)</b>  | 0.278 (<0.001)       | 0.282 (<0.001)        | 0.47 (<0.001)        | <b>0.085 (0.181)</b>  | <b>0.11 (0.081)</b>   | <b>0.075 (0.239)</b> |
| 65.Wrist circumf             | <b>-0.069 (0.28)</b>  | <b>-0.078 (0.221)</b> | <b>0.008 (0.899)</b> | <b>0.09 (0.157)</b>   | <b>0.109 (0.085)</b>  | 0.283 (<0.001)       | 0.298 (<0.001)        | 0.239 (<0.001)       | 0.415 (<0.001)        | 0.404 (<0.001)       | 0.135 (0.033)         | 0.298 (<0.001)        | 0.371 (<0.001)       |

Table 5.8. Pearson Correlation coefficients between different anthropometric measurements (cont'd).

| Measurement                | 27                   | 28                    | 29                   | 30                   | 31                   | 32                   | 33                   | 34                    | 35                    | 36                   | 37                   | 38                   | 39                    |
|----------------------------|----------------------|-----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|-----------------------|-----------------------|----------------------|----------------------|----------------------|-----------------------|
| 28.Foot brt                | 0.293 (<0.001)       |                       |                      |                      |                      |                      |                      |                       |                       |                      |                      |                      |                       |
| 29.Sit. ht(e)              | 0.321 (<0.001)       | 0.192 (0.002)         |                      |                      |                      |                      |                      |                       |                       |                      |                      |                      |                       |
| 30.Sit. ht (n)             | 0.319 (<0.001)       | 0.203 (0.001)         | 0.993 (<0.001)       |                      |                      |                      |                      |                       |                       |                      |                      |                      |                       |
| 31.Sit. eye ht (e)         | 0.353 (<0.001)       | 0.126 (0.047)         | 0.873 (<0.001)       | 0.864 (<0.001)       |                      |                      |                      |                       |                       |                      |                      |                      |                       |
| 32.Sit. eye ht (n)         | 0.352 (<0.001)       | 0.137 (0.031)         | 0.869 (<0.001)       | 0.873 (<0.001)       | 0.994 (<0.001)       |                      |                      |                       |                       |                      |                      |                      |                       |
| 33.Sit. acr. (shld) ht (e) | 0.286 (<0.001)       | 0.201 (0.001)         | 0.728 (<0.001)       | 0.733 (<0.001)       | 0.768 (<0.001)       | 0.775 (<0.001)       |                      |                       |                       |                      |                      |                      |                       |
| 34.Sit. acr. (shld) ht (n) | 0.257 (<0.001)       | 0.287 (<0.001)        | 0.711 (<0.001)       | 0.725 (<0.001)       | 0.701 (<0.001)       | 0.716 (<0.001)       | 0.955 (<0.001)       |                       |                       |                      |                      |                      |                       |
| 35.Sit. elbow rest ht (n)  | <b>0.023 (0.715)</b> | 0.254 (<0.001)        | 0.282 (<0.001)       | 0.307 (<0.001)       | 0.21 (0.001)         | 0.235 (<0.001)       | 0.37 (<0.001)        | 0.446 (<0.001)        |                       |                      |                      |                      |                       |
| 36.Knee ht                 | 0.495 (<0.001)       | <b>0.03 (0.633)</b>   | 0.5 (<0.001)         | 0.471 (<0.001)       | 0.485 (<0.001)       | 0.458 (<0.001)       | 0.403 (<0.001)       | 0.344 (<0.001)        | -0.176 (0.005)        |                      |                      |                      |                       |
| 37.Popliteal ht            | 0.405 (<0.001)       | <b>-0.083 (0.189)</b> | 0.32 (<0.001)        | 0.297 (<0.001)       | 0.382 (<0.001)       | 0.36 (<0.001)        | 0.274 (<0.001)       | 0.185 (0.003)         | -0.271 (<0.001)       | 0.74 (<0.001)        |                      |                      |                       |
| 38.Buttock-knee lgt        | 0.571 (<0.001)       | <b>0.017 (0.786)</b>  | 0.381 (<0.001)       | 0.374 (<0.001)       | 0.393 (<0.001)       | 0.388 (<0.001)       | 0.401 (<0.001)       | 0.343 (<0.001)        | <b>-0.002 (0.98)</b>  | 0.624 (<0.001)       | 0.456 (<0.001)       |                      |                       |
| 39.Buttock-popliteal lgt   | 0.477 (<0.001)       | -0.128 (0.043)        | 0.221 (<0.001)       | 0.223 (<0.001)       | 0.309 (<0.001)       | 0.313 (<0.001)       | 0.263 (<0.001)       | 0.184 (0.004)         | <b>-0.075 (0.236)</b> | 0.52 (<0.001)        | 0.414 (<0.001)       | 0.797 (<0.001)       |                       |
| 40.Thigh clearance         | 0.287 (<0.001)       | 0.219 (<0.001)        | 0.247 (<0.001)       | 0.24 (<0.001)        | 0.296 (<0.001)       | 0.291 (<0.001)       | 0.354 (<0.001)       | 0.349 (<0.001)        | 0.18 (0.004)          | 0.411 (<0.001)       | 0.171 (0.007)        | 0.464 (<0.001)       | 0.298 (<0.001)        |
| 41.Buttock-Leg Lgt         | 0.465 (<0.001)       | 0.17 (0.007)          | 0.423 (<0.001)       | 0.407 (<0.001)       | 0.438 (<0.001)       | 0.423 (<0.001)       | 0.404 (<0.001)       | 0.345 (<0.001)        | <b>-0.079 (0.213)</b> | 0.701 (<0.001)       | 0.547 (<0.001)       | 0.648 (<0.001)       | 0.44 (<0.001)         |
| 42.Sit.vertical grip rch   | 0.256 (<0.001)       | <b>0.044 (0.485)</b>  | 0.58 (<0.001)        | 0.565 (<0.001)       | 0.579 (<0.001)       | 0.566 (<0.001)       | 0.545 (<0.001)       | 0.48 (<0.001)         | <b>0.002 (0.969)</b>  | 0.508 (<0.001)       | 0.324 (<0.001)       | 0.355 (<0.001)       | 0.206 (0.001)         |
| 43.Sit.vertical th-tip rch | 0.281 (<0.001)       | <b>-0.008 (0.899)</b> | 0.592 (<0.001)       | 0.571 (<0.001)       | 0.59 (<0.001)        | 0.571 (<0.001)       | 0.558 (<0.001)       | 0.478 (<0.001)        | <b>0 (1)</b>          | 0.593 (<0.001)       | 0.406 (<0.001)       | 0.395 (<0.001)       | 0.225 (<0.001)        |
| 44.Sit.vertical fngtip rch | 0.342 (<0.001)       | <b>0.061 (0.338)</b>  | 0.633 (<0.001)       | 0.615 (<0.001)       | 0.626 (<0.001)       | 0.61 (<0.001)        | 0.588 (<0.001)       | 0.517 (<0.001)        | <b>0.04 (0.525)</b>   | 0.577 (<0.001)       | 0.42 (<0.001)        | 0.446 (<0.001)       | 0.252 (<0.001)        |
| 45.Sit.forward grip rch    | 0.242 (<0.001)       | <b>-0.073 (0.253)</b> | 0.391 (<0.001)       | 0.377 (<0.001)       | 0.385 (<0.001)       | 0.372 (<0.001)       | 0.276 (<0.001)       | 0.221 (<0.001)        | -0.13 (0.039)         | 0.542 (<0.001)       | 0.304 (<0.001)       | 0.331 (<0.001)       | 0.252 (<0.001)        |
| 46.Sit.forward th-tip rch  | 0.28 (<0.001)        | -0.18 (0.004)         | 0.31 (<0.001)        | 0.286 (<0.001)       | 0.325 (<0.001)       | 0.303 (<0.001)       | 0.239 (<0.001)       | 0.144 (0.023)         | -0.235 (<0.001)       | 0.581 (<0.001)       | 0.378 (<0.001)       | 0.39 (<0.001)        | 0.318 (<0.001)        |
| 47.Sit.forward fngtip rch  | 0.316 (<0.001)       | -0.207 (0.001)        | 0.311 (<0.001)       | 0.284 (<0.001)       | 0.314 (<0.001)       | 0.289 (<0.001)       | 0.166 (0.009)        | <b>0.059 (0.35)</b>   | -0.265 (<0.001)       | 0.542 (<0.001)       | 0.395 (<0.001)       | 0.47 (<0.001)        | 0.387 (<0.001)        |
| 48.Head circumf            | 0.289 (<0.001)       | <b>0.104 (0.102)</b>  | 0.478 (<0.001)       | 0.478 (<0.001)       | 0.429 (<0.001)       | 0.431 (<0.001)       | 0.488 (<0.001)       | 0.451 (<0.001)        | 0.158 (0.012)         | 0.327 (<0.001)       | 0.182 (0.004)        | 0.306 (<0.001)       | 0.14 (0.027)          |
| 49.Head lgt                | 0.252 (<0.001)       | <b>0.116 (0.068)</b>  | 0.248 (<0.001)       | 0.247 (<0.001)       | 0.172 (0.006)        | 0.171 (0.007)        | 0.146 (0.021)        | <b>0.119 (0.059)</b>  | <b>-0.042 (0.511)</b> | 0.241 (<0.001)       | 0.15 (0.018)         | 0.149 (0.018)        | <b>0.046 (0.473)</b>  |
| 50.Head brt                | 0.151 (0.017)        | 0.126 (0.046)         | 0.355 (<0.001)       | 0.351 (<0.001)       | 0.336 (<0.001)       | 0.333 (<0.001)       | 0.326 (<0.001)       | 0.273 (<0.001)        | 0.15 (0.017)          | <b>0.1 (0.116)</b>   | <b>0.05 (0.434)</b>  | <b>0.075 (0.239)</b> | <b>0.017 (0.792)</b>  |
| 51.Ment-sellion (face) lgt | 0.359 (<0.001)       | 0.455 (<0.001)        | 0.315 (<0.001)       | 0.329 (<0.001)       | 0.32 (<0.001)        | 0.334 (<0.001)       | 0.353 (<0.001)       | 0.403 (<0.001)        | 0.324 (<0.001)        | 0.136 (0.032)        | <b>0.083 (0.191)</b> | 0.191 (0.002)        | <b>-0.012 (0.855)</b> |
| 52.Bizygomatic (face) brt  | 0.279 (<0.001)       | <b>-0.05 (0.433)</b>  | <b>0.075 (0.237)</b> | <b>0.069 (0.276)</b> | 0.189 (0.003)        | 0.184 (0.003)        | <b>0.085 (0.178)</b> | <b>-0.044 (0.493)</b> | <b>-0.084 (0.186)</b> | 0.202 (0.001)        | 0.296 (<0.001)       | 0.264 (<0.001)       | 0.347 (<0.001)        |
| 53.Neck circumf            | 0.301 (<0.001)       | <b>0.1 (0.116)</b>    | 0.249 (<0.001)       | 0.244 (<0.001)       | 0.302 (<0.001)       | 0.299 (<0.001)       | 0.367 (<0.001)       | 0.296 (<0.001)        | 0.263 (<0.001)        | 0.215 (0.001)        | <b>0.11 (0.082)</b>  | 0.394 (<0.001)       | 0.296 (<0.001)        |
| 54.Chest circumf           | <b>0.074 (0.243)</b> | <b>-0.062 (0.332)</b> | <b>0.095 (0.133)</b> | <b>0.079 (0.215)</b> | 0.14 (0.027)         | 0.124 (0.05)         | 0.173 (0.006)        | <b>0.104 (0.101)</b>  | 0.2 (0.001)           | 0.277 (<0.001)       | <b>0.108 (0.089)</b> | 0.315 (<0.001)       | 0.245 (<0.001)        |
| 55.Waist circumf           | <b>0.031 (0.622)</b> | <b>-0.022 (0.726)</b> | <b>0.01 (0.869)</b>  | <b>0.002 (0.979)</b> | <b>0.011 (0.861)</b> | <b>0.003 (0.968)</b> | <b>0.122 (0.055)</b> | <b>0.09 (0.158)</b>   | 0.304 (<0.001)        | <b>0.122 (0.055)</b> | <b>0.003 (0.967)</b> | 0.265 (<0.001)       | 0.192 (0.002)         |
| 56.Hip brt (sit.)          | <b>0.08 (0.209)</b>  | <b>0.055 (0.382)</b>  | 0.195 (0.002)        | 0.193 (0.002)        | 0.185 (0.003)        | 0.183 (0.004)        | 0.287 (<0.001)       | 0.254 (<0.001)        | 0.194 (0.002)         | 0.326 (<0.001)       | 0.129 (0.042)        | 0.287 (<0.001)       | 0.157 (0.013)         |
| 57.Sit. e-to-e brt (n)     | 0.199 (0.002)        | <b>0.012 (0.847)</b>  | 0.207 (0.001)        | 0.204 (0.001)        | 0.282 (<0.001)       | 0.28 (<0.001)        | 0.345 (<0.001)       | 0.298 (<0.001)        | 0.344 (<0.001)        | 0.247 (<0.001)       | <b>0.062 (0.33)</b>  | 0.443 (<0.001)       | 0.354 (<0.001)        |
| 58.Shld biacr. brt         | 0.317 (<0.001)       | <b>0.106 (0.096)</b>  | 0.367 (<0.001)       | 0.346 (<0.001)       | 0.344 (<0.001)       | 0.325 (<0.001)       | 0.311 (<0.001)       | 0.261 (<0.001)        | <b>0.037 (0.565)</b>  | 0.43 (<0.001)        | 0.298 (<0.001)       | 0.347 (<0.001)       | 0.165 (0.009)         |
| 59.Shld bideltoid brt      | 0.356 (<0.001)       | <b>0.054 (0.392)</b>  | 0.293 (<0.001)       | 0.277 (<0.001)       | 0.298 (<0.001)       | 0.284 (<0.001)       | 0.325 (<0.001)       | 0.299 (<0.001)        | 0.228 (<0.001)        | 0.37 (<0.001)        | 0.271 (<0.001)       | 0.437 (<0.001)       | 0.299 (<0.001)        |
| 60.Hand lgt                | 0.684 (<0.001)       | 0.17 (0.007)          | 0.362 (<0.001)       | 0.369 (<0.001)       | 0.441 (<0.001)       | 0.449 (<0.001)       | 0.417 (<0.001)       | 0.36 (<0.001)         | <b>0.109 (0.086)</b>  | 0.41 (<0.001)        | 0.4 (<0.001)         | 0.508 (<0.001)       | 0.423 (<0.001)        |
| 61.Hand brt                | 0.229 (<0.001)       | 0.53 (<0.001)         | 0.202 (0.001)        | 0.222 (<0.001)       | 0.262 (<0.001)       | 0.282 (<0.001)       | 0.378 (<0.001)       | 0.406 (<0.001)        | 0.31 (<0.001)         | <b>0.061 (0.338)</b> | <b>0.017 (0.788)</b> | <b>0.082 (0.197)</b> | <b>-0.041 (0.524)</b> |
| 62.Palm lgt perp           | 0.436 (<0.001)       | 0.233 (<0.001)        | 0.381 (<0.001)       | 0.403 (<0.001)       | 0.324 (<0.001)       | 0.347 (<0.001)       | 0.404 (<0.001)       | 0.432 (<0.001)        | 0.225 (<0.001)        | 0.359 (<0.001)       | 0.195 (0.002)        | 0.337 (<0.001)       | 0.236 (<0.001)        |
| 63.Index finger lgt        | 0.427 (<0.001)       | 0.246 (<0.001)        | 0.334 (<0.001)       | 0.343 (<0.001)       | 0.392 (<0.001)       | 0.403 (<0.001)       | 0.485 (<0.001)       | 0.489 (<0.001)        | 0.13 (0.039)          | 0.323 (<0.001)       | 0.231 (<0.001)       | 0.29 (<0.001)        | 0.21 (0.001)          |
| 64.Hand circumf            | 0.338 (<0.001)       | 0.335 (<0.001)        | 0.206 (0.001)        | 0.23 (<0.001)        | 0.264 (<0.001)       | 0.288 (<0.001)       | 0.366 (<0.001)       | 0.414 (<0.001)        | 0.434 (<0.001)        | <b>0.039 (0.544)</b> | <b>0.03 (0.634)</b>  | 0.363 (<0.001)       | 0.254 (<0.001)        |
| 65.Wrist circumf           | 0.274 (<0.001)       | <b>-0.039 (0.542)</b> | 0.218 (0.001)        | 0.211 (0.001)        | 0.33 (<0.001)        | 0.325 (<0.001)       | 0.365 (<0.001)       | 0.303 (<0.001)        | 0.193 (0.002)         | 0.234 (<0.001)       | 0.198 (0.002)        | 0.442 (<0.001)       | 0.411 (<0.001)        |

Table 5.8. Pearson Correlation coefficients between different anthropometric measurements (cont'd).

| Measurement                  | 40                   | 41             | 42                   | 43                   | 44                   | 45                    | 46                    | 47                    | 48             | 49                    | 50             | 51                   | 52                   |
|------------------------------|----------------------|----------------|----------------------|----------------------|----------------------|-----------------------|-----------------------|-----------------------|----------------|-----------------------|----------------|----------------------|----------------------|
| 41. Buttock-Leg Lgt          | 0.381 (<0.001)       |                |                      |                      |                      |                       |                       |                       |                |                       |                |                      |                      |
| 42. Sit. vertical grip rch   | 0.166 (0.009)        | 0.473 (<0.001) |                      |                      |                      |                       |                       |                       |                |                       |                |                      |                      |
| 43. Sit. vertical th-tip rch | 0.207 (0.001)        | 0.513 (<0.001) | 0.938 (<0.001)       |                      |                      |                       |                       |                       |                |                       |                |                      |                      |
| 44. Sit. vertical fngtip rch | 0.22 (<0.001)        | 0.516 (<0.001) | 0.896 (<0.001)       | 0.952 (<0.001)       |                      |                       |                       |                       |                |                       |                |                      |                      |
| 45. Sit. forward grip rch    | 0.129 (0.041)        | 0.419 (<0.001) | 0.666 (<0.001)       | 0.734 (<0.001)       | 0.665 (<0.001)       |                       |                       |                       |                |                       |                |                      |                      |
| 46. Sit. forward th-tip rch  | <b>0.1 (0.116)</b>   | 0.443 (<0.001) | 0.6 (<0.001)         | 0.706 (<0.001)       | 0.646 (<0.001)       | 0.901 (<0.001)        |                       |                       |                |                       |                |                      |                      |
| 47. Sit. forward fngtip rch  | <b>0.08 (0.205)</b>  | 0.448 (<0.001) | 0.553 (<0.001)       | 0.643 (<0.001)       | 0.623 (<0.001)       | 0.821 (<0.001)        | 0.903 (<0.001)        |                       |                |                       |                |                      |                      |
| 48. Head circumf             | 0.271 (<0.001)       | 0.31 (<0.001)  | 0.316 (<0.001)       | 0.335 (<0.001)       | 0.349 (<0.001)       | 0.255 (<0.001)        | 0.23 (<0.001)         | 0.202 (0.001)         |                |                       |                |                      |                      |
| 49. Head lgt                 | <b>0.122 (0.055)</b> | 0.204 (0.001)  | 0.203 (0.001)        | 0.212 (0.001)        | 0.187 (0.003)        | 0.181 (0.004)         | 0.177 (0.005)         | 0.177 (0.005)         | 0.638 (<0.001) |                       |                |                      |                      |
| 50. Head brt                 | 0.156 (0.013)        | 0.195 (0.002)  | 0.252 (<0.001)       | 0.256 (<0.001)       | 0.271 (<0.001)       | 0.163 (0.01)          | <b>0.11 (0.081)</b>   | <b>0.114 (0.071)</b>  | 0.573 (<0.001) | 0.149 (0.018)         |                |                      |                      |
| 51. Ment-sellion (face) lgt  | 0.282 (<0.001)       | 0.308 (<0.001) | <b>0.1 (0.114)</b>   | <b>0.092 (0.145)</b> | 0.173 (0.006)        | <b>0.042 (0.509)</b>  | <b>-0.037 (0.557)</b> | <b>-0.059 (0.351)</b> | 0.36 (<0.001)  | 0.148 (0.019)         | 0.303 (<0.001) |                      |                      |
| 52. Bizygomatic (face) brt   | 0.231 (<0.001)       | 0.14 (0.027)   | <b>0.061 (0.339)</b> | <b>0.11 (0.082)</b>  | <b>0.095 (0.134)</b> | 0.153 (0.015)         | 0.212 (0.001)         | 0.241 (<0.001)        | 0.286 (<0.001) | 0.265 (<0.001)        | 0.31 (<0.001)  | <b>0.074 (0.246)</b> |                      |
| 53. Neck circumf             | 0.393 (<0.001)       | 0.291 (<0.001) | 0.157 (0.013)        | 0.229 (<0.001)       | 0.241 (<0.001)       | 0.193 (0.002)         | 0.231 (<0.001)        | 0.24 (<0.001)         | 0.529 (<0.001) | 0.24 (<0.001)         | 0.432 (<0.001) | 0.296 (<0.001)       | 0.427 (<0.001)       |
| 54. Chest circumf            | 0.431 (<0.001)       | 0.26 (<0.001)  | 0.173 (0.006)        | 0.287 (<0.001)       | 0.231 (<0.001)       | 0.265 (<0.001)        | 0.291 (<0.001)        | 0.279 (<0.001)        | 0.191 (0.002)  | <b>0.009 (0.884)</b>  | 0.181 (0.004)  | <b>0.002 (0.969)</b> | 0.278 (<0.001)       |
| 55. Waist circumf            | 0.384 (<0.001)       | 0.136 (0.031)  | <b>0.03 (0.634)</b>  | 0.135 (0.033)        | <b>0.11 (0.083)</b>  | 0.165 (0.009)         | 0.185 (0.003)         | 0.194 (0.002)         | 0.161 (0.011)  | <b>-0.006 (0.925)</b> | 0.175 (0.006)  | <b>0.04 (0.531)</b>  | 0.271 (<0.001)       |
| 56. Hip brt (sit.)           | 0.491 (<0.001)       | 0.255 (<0.001) | 0.267 (<0.001)       | 0.331 (<0.001)       | 0.265 (<0.001)       | 0.225 (<0.001)        | 0.203 (0.001)         | 0.129 (0.042)         | 0.274 (<0.001) | <b>0.113 (0.074)</b>  | 0.168 (0.008)  | <b>0.084 (0.185)</b> | 0.227 (<0.001)       |
| 57. Sit. e-to-e brt (n)      | 0.412 (<0.001)       | 0.229 (<0.001) | 0.148 (0.02)         | 0.242 (<0.001)       | 0.256 (<0.001)       | <b>0.116 (0.067)</b>  | 0.144 (0.023)         | 0.156 (0.014)         | 0.279 (<0.001) | <b>-0.035 (0.586)</b> | 0.279 (<0.001) | 0.183 (0.004)        | 0.269 (<0.001)       |
| 58. Shld biacr. brt          | 0.422 (<0.001)       | 0.411 (<0.001) | 0.321 (<0.001)       | 0.402 (<0.001)       | 0.423 (<0.001)       | 0.323 (<0.001)        | 0.353 (<0.001)        | 0.366 (<0.001)        | 0.379 (<0.001) | 0.22 (<0.001)         | 0.333 (<0.001) | 0.237 (<0.001)       | 0.286 (<0.001)       |
| 59. Shld bideltoid brt       | 0.452 (<0.001)       | 0.364 (<0.001) | 0.236 (<0.001)       | 0.322 (<0.001)       | 0.334 (<0.001)       | 0.235 (<0.001)        | 0.252 (<0.001)        | 0.286 (<0.001)        | 0.411 (<0.001) | 0.185 (0.003)         | 0.319 (<0.001) | 0.326 (<0.001)       | 0.327 (<0.001)       |
| 60. Hand lgt                 | 0.312 (<0.001)       | 0.415 (<0.001) | 0.23 (<0.001)        | 0.272 (<0.001)       | 0.343 (<0.001)       | 0.185 (0.003)         | 0.239 (<0.001)        | 0.268 (<0.001)        | 0.404 (<0.001) | 0.267 (<0.001)        | 0.286 (<0.001) | 0.399 (<0.001)       | 0.389 (<0.001)       |
| 61. Hand brt                 | 0.286 (<0.001)       | 0.157 (0.013)  | <b>0.117 (0.065)</b> | 0.136 (0.031)        | 0.207 (0.001)        | <b>-0.044 (0.484)</b> | <b>-0.096 (0.131)</b> | -0.146 (0.02)         | 0.166 (0.009)  | <b>0.065 (0.308)</b>  | 0.16 (0.011)   | 0.479 (<0.001)       | <b>0.078 (0.219)</b> |
| 62. Palm lgt perp            | 0.26 (<0.001)        | 0.382 (<0.001) | 0.309 (<0.001)       | 0.357 (<0.001)       | 0.367 (<0.001)       | 0.224 (<0.001)        | 0.204 (0.001)         | 0.165 (0.009)         | 0.256 (<0.001) | 0.185 (0.003)         | 0.178 (0.005)  | 0.387 (<0.001)       | <b>0.02 (0.757)</b>  |
| 63. Index finger lgt         | 0.335 (<0.001)       | 0.336 (<0.001) | 0.187 (0.003)        | 0.22 (<0.001)        | 0.252 (<0.001)       | <b>0.1 (0.115)</b>    | <b>0.12 (0.059)</b>   | <b>0.049 (0.442)</b>  | 0.371 (<0.001) | 0.216 (0.001)         | 0.215 (0.001)  | 0.415 (<0.001)       | 0.143 (0.024)        |
| 64. Hand circumf             | 0.293 (<0.001)       | 0.187 (0.003)  | <b>0.03 (0.635)</b>  | <b>0.041 (0.514)</b> | 0.152 (0.016)        | <b>-0.096 (0.132)</b> | <b>-0.107 (0.09)</b>  | <b>-0.086 (0.175)</b> | 0.16 (0.011)   | -0.137 (0.03)         | 0.129 (0.042)  | 0.451 (<0.001)       | <b>0.053 (0.407)</b> |
| 65. Wrist circumf            | 0.345 (<0.001)       | 0.219 (<0.001) | <b>0.093 (0.144)</b> | 0.149 (0.018)        | 0.21 (0.001)         | <b>0.048 (0.45)</b>   | 0.149 (0.018)         | 0.182 (0.004)         | 0.293 (<0.001) | <b>-0.03 (0.632)</b>  | 0.294 (<0.001) | 0.264 (<0.001)       | 0.343 (<0.001)       |

| Measurement             | 53             | 54                   | 55                    | 56                   | 57             | 58                   | 59             | 60             | 61             | 62             | 63             | 64             |
|-------------------------|----------------|----------------------|-----------------------|----------------------|----------------|----------------------|----------------|----------------|----------------|----------------|----------------|----------------|
| 54. Chest circumf       | 0.572 (<0.001) |                      |                       |                      |                |                      |                |                |                |                |                |                |
| 55. Waist circumf       | 0.63 (<0.001)  | 0.848 (<0.001)       |                       |                      |                |                      |                |                |                |                |                |                |
| 56. Hip brt (sit.)      | 0.325 (<0.001) | 0.632 (<0.001)       | 0.558 (<0.001)        |                      |                |                      |                |                |                |                |                |                |
| 57. Sit. e-to-e brt (n) | 0.622 (<0.001) | 0.575 (<0.001)       | 0.549 (<0.001)        | 0.462 (<0.001)       |                |                      |                |                |                |                |                |                |
| 58. Shld biacr. brt     | 0.395 (<0.001) | 0.408 (<0.001)       | 0.332 (<0.001)        | 0.411 (<0.001)       | 0.378 (<0.001) |                      |                |                |                |                |                |                |
| 59. Shld bideltoid brt  | 0.561 (<0.001) | 0.549 (<0.001)       | 0.519 (<0.001)        | 0.473 (<0.001)       | 0.626 (<0.001) | 0.757 (<0.001)       |                |                |                |                |                |                |
| 60. Hand lgt            | 0.451 (<0.001) | <b>0.036 (0.575)</b> | <b>0.011 (0.859)</b>  | <b>0.053 (0.406)</b> | 0.33 (<0.001)  | 0.311 (<0.001)       | 0.377 (<0.001) |                |                |                |                |                |
| 61. Hand brt            | 0.281 (<0.001) | 0.192 (0.002)        | 0.187 (0.003)         | 0.177 (0.005)        | 0.274 (<0.001) | <b>0.112 (0.077)</b> | 0.165 (0.009)  | 0.28 (<0.001)  |                |                |                |                |
| 62. Palm lgt perp       | 0.299 (<0.001) | 0.198 (0.002)        | 0.126 (0.047)         | 0.206 (0.001)        | 0.276 (<0.001) | 0.276 (<0.001)       | 0.34 (<0.001)  | 0.548 (<0.001) | 0.423 (<0.001) |                |                |                |
| 63. Index finger lgt    | 0.352 (<0.001) | <b>0.004 (0.949)</b> | <b>-0.064 (0.313)</b> | <b>0.081 (0.203)</b> | 0.253 (<0.001) | 0.214 (0.001)        | 0.263 (<0.001) | 0.708 (<0.001) | 0.449 (<0.001) | 0.535 (<0.001) |                |                |
| 64. Hand circumf        | 0.479 (<0.001) | 0.195 (0.002)        | 0.277 (<0.001)        | <b>0.042 (0.506)</b> | 0.495 (<0.001) | <b>0.095 (0.135)</b> | 0.306 (<0.001) | 0.465 (<0.001) | 0.634 (<0.001) | 0.439 (<0.001) | 0.471 (<0.001) |                |
| 65. Wrist circumf       | 0.604 (<0.001) | 0.254 (<0.001)       | 0.312 (<0.001)        | <b>0.104 (0.101)</b> | 0.565 (<0.001) | 0.236 (<0.001)       | 0.398 (<0.001) | 0.599 (<0.001) | 0.311 (<0.001) | 0.257 (<0.001) | 0.541 (<0.001) | 0.617 (<0.001) |

Table 5.9. Pearson correlation among anthropometric measurements, BMIP and age.

| Meas. | Body mass (kg)      | Stature (e)         | Stature (n)         | Eye ht (e)          | Eye ht (n)          | Acr. (shld) ht (e)   | Acr. (shld) ht (n)  | Elbow ht (n)        | Fngtip ht (n)       | Th-tip ht (n)       | Fist(gr.ax, knck)ht (n) | Waist ht (n)        | Vertical grip rch   |
|-------|---------------------|---------------------|---------------------|---------------------|---------------------|----------------------|---------------------|---------------------|---------------------|---------------------|-------------------------|---------------------|---------------------|
| BMIP  | 0.842<br>(p<0.001)  | -0.131<br>(p=0.038) | -0.131<br>(p=0.039) | -0.134<br>(p=0.034) | -0.132<br>(p=0.037) | -0.065<br>(p=0.309)  | -0.060<br>(p=0.341) | -0.022<br>(p=0.728) | -0.001<br>(p=0.992) | 0.032<br>(p=0.615)  | -0.034<br>(p=0.595)     | -0.087<br>(p=0.172) | -0.102<br>(p=0.108) |
| AGE   | -0.077<br>(p=0.222) | -0.508<br>(p<0.001) | -0.503<br>(p<0.001) | -0.486<br>(p<0.001) | -0.480<br>(p<0.001) | -0.2439<br>(p<0.001) | -0.423<br>(p<0.001) | -0.385<br>(p<0.001) | -0.397<br>(p<0.001) | -0.349<br>(p<0.001) | -0.328<br>(p<0.001)     | -0.209<br>(p=0.001) | -0.458<br>(p<0.001) |

| Meas. | Vertical th-tip rch | Vertical fngtip rch | Forward grip rch    | Forward th-tip rch  | Forward fngtip rch  | Span                | Elbow span          | Chest (bust) depth | Chest (bust) brt    | Stand. e-to-e brt   | Shld-elbow lgt      | Shld-fngtip lgt     | Shld-fist (grip axis) lgt |
|-------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|--------------------|---------------------|---------------------|---------------------|---------------------|---------------------------|
| BMIP  | -0.108<br>(p=0.087) | -0.111<br>(p=0.081) | -0.042<br>(p=0.513) | -0.105<br>(p=0.098) | -0.071<br>(p=0.266) | -0.083<br>(p=0.192) | -0.002<br>(p=0.971) | 0.531<br>(p<0.001) | 0.493<br>(p<0.001)  | 0.487<br>(p<0.001)  | -0.081<br>(p=0.203) | -0.091<br>(p=0.151) | -0.057<br>(p=0.365)       |
| AGE   | -0.433<br>(p<0.001) | -0.440<br>(p<0.001) | -0.184<br>(p=0.003) | -0.136<br>(p=0.032) | -0.232<br>(p<0.001) | -0.428<br>(p<0.001) | -0.329<br>(p<0.001) | 0.093<br>(p=0.146) | -0.138<br>(p=0.029) | -0.046<br>(p=0.469) | -0.22<br>(p<0.001)  | -0.292<br>(p<0.001) | -0.306<br>(p<0.001)       |

| Meas. | Foot lgt           | Foot brt            | Sit. ht(e)          | Sit. ht (n)         | Sit. eye ht (e)     | Sit. eye ht (n)     | Sit. acr. (shld) ht (e) | Sit. acr. (shld) ht (n) | Sit. elbow rest ht (n) | Knee ht             | Popliteal ht        | Buttock-knee lgt    | Buttock-popliteal lgt |
|-------|--------------------|---------------------|---------------------|---------------------|---------------------|---------------------|-------------------------|-------------------------|------------------------|---------------------|---------------------|---------------------|-----------------------|
| BMIP  | 0.032<br>(p=0.615) | 0.099<br>(p=0.119)  | 0.009<br>(p=0.883)  | 0.014<br>(p=0.823)  | -0.011<br>(p=0.862) | -0.006<br>(p=0.921) | 0.12<br>(p=0.058)       | 0.123<br>(p=0.052)      | 0.343<br>(p<0.001)     | -0.033<br>(p=0.604) | -0.084<br>(p=0.186) | 0.185<br>(p=0.003)  | 0.089<br>(p=0.158)    |
| AGE   | -0.16<br>(p=0.011) | -0.006<br>(p=0.929) | -0.353<br>(p<0.001) | -0.331<br>(p<0.001) | -0.342<br>(p<0.001) | -0.321<br>(p<0.001) | -0.249<br>(p<0.001)     | -0.207<br>(p=0.001)     | 0.168<br>(p=0.008)     | -0.393<br>(p<0.001) | -0.322<br>(p<0.001) | -0.213<br>(p=0.001) | -0.093<br>(p=0.141)   |

| Meas. | Thigh clearance    | Buttock-Leg Lgt     | Sit.vertical grip rch | Sit.vertical th-tip rch | Sit.vertical fngtip rch | Sit.forward grip rch | Sit.forward th-tip rch | Sit.forward fngtip rch | Head circumf        | Head lgt            | Head brt            | Ment-sellion (face) lgt | Bizygomatic (face) brt |
|-------|--------------------|---------------------|-----------------------|-------------------------|-------------------------|----------------------|------------------------|------------------------|---------------------|---------------------|---------------------|-------------------------|------------------------|
| BMIP  | 0.418<br>(p<0.001) | 0.048<br>(p=0.454)  | -0.022<br>(p=0.735)   | 0.021<br>(p=0.736)      | 0.026<br>(p=0.682)      | -0.022<br>(p=0.734)  | -0.037<br>(p=0.564)    | -0.003<br>(p=0.961)    | 0.164<br>(p=0.009)  | -0.006<br>(p=0.93)  | 0.195<br>(p=0.002)  | 0.124<br>(p=0.051)      | 0.147<br>(p=0.02)      |
| AGE   | -0.11<br>(p=0.083) | -0.362<br>(p<0.001) | -0.426<br>(p<0.001)   | -0.414<br>(p<0.001)     | -0.422<br>(p<0.001)     | -0.232<br>(p<0.001)  | -0.222<br>(p<0.001)    | -0.238<br>(p<0.001)    | -0.243<br>(p<0.001) | -0.243<br>(p<0.001) | -0.153<br>(p=0.016) | -0.011<br>(p=0.863)     | -0.084<br>(p=0.184)    |

| Meas. | Neck circumf       | Chest circumf      | Waist circumf      | Hip brt (sit.)     | Sit. e-to-e brt (n) | Shld biacr. brt     | Shld bideltoid brt  | Hand lgt            | Hand brt           | Palm lgt perp       | Index finger lgt    | Hand circumf       | Wrist circumf      |
|-------|--------------------|--------------------|--------------------|--------------------|---------------------|---------------------|---------------------|---------------------|--------------------|---------------------|---------------------|--------------------|--------------------|
| BMIP  | 0.536<br>(p<0.001) | 0.607<br>(p<0.001) | 0.693<br>(p<0.001) | 0.516<br>(p<0.001) | 0.489<br>(p<0.001)  | 0.321<br>(p<0.001)  | 0.491<br>(p<0.001)  | 0.041<br>(p=0.519)  | 0.197<br>(p=0.002) | 0.109<br>(p=0.086)  | 0.053<br>(p=0.403)  | 0.349<br>(p<0.001) | 0.329<br>(p<0.001) |
| AGE   | 0.055<br>(p=0.383) | 0.053<br>(p=0.402) | 0.221<br>(p<0.001) | -0.12<br>(p=0.059) | -0.047<br>(p=0.46)  | -0.278<br>(p<0.001) | -0.191<br>(p=0.002) | -0.113<br>(p=0.074) | 0.129<br>(p=0.042) | -0.043<br>(p=0.503) | -0.035<br>(p=0.581) | 0.225<br>(p<0.001) | 0.12<br>(p=0.058)  |

Table 5.10. Pearson correlation among some anthropometric measurements including body mass and habits/activities.

| Meas.            | Smoking habit<br>(pocket/day) |         | Drinking habits<br>(times/week) |         | Frequency of sportive<br>activities (times/week) |         | Frequency of health<br>control (times/year) |         |
|------------------|-------------------------------|---------|---------------------------------|---------|--------------------------------------------------|---------|---------------------------------------------|---------|
|                  | Coefficient                   | p-value | Coefficient                     | p-value | Coefficient                                      | p-value | Coefficient                                 | p-value |
| <b>Body Mass</b> | 0.019                         | 0.766   | 0.365                           | <0.001  | -0.339                                           | <0.001  | -0.047                                      | 0.457   |

Moreover, by using Pearson Correlation, the correlation between body mass and smoking/drinking habits, frequency of sportive activities, and control on his health with each others are given in Tables 5.10. Results indicated that body mass is significantly and positively correlated with drinking habit. Also, frequency of sportive activities was found as a significant factor (negatively correlated) with body mass. Although there is not significant correlation between body mass and smoking habit, the increase in the number of cigarette pockets per day results in the increase in body mass value.

### 5.2.3. Analysis of Variance

The assumptions of the analysis were checked at the beginning of analysis of variance (ANOVA) process.

a. Normality Assumption: Normality check has been performed by using Anderson-Darling normality test ( $\alpha = 0.05$ ) in Minitab 16.0. According to Anderson-Darling normality test, the p-value of residuals of body mass data is 0.171. Since it is greater than 0.05, the null hypothesis, which says data follow normal distribution, cannot be rejected. Therefore, the residual data for subjects follow normal distribution. Also, normality can be checked by looking at the distribution of residuals. Figure 5.9 shows the result of normality plots of residuals for body mass. By looking at the figure, it can be said that normality exists.

Next, this assumption was checked for all other measurements, and it was seen that data follow normal distribution for them.

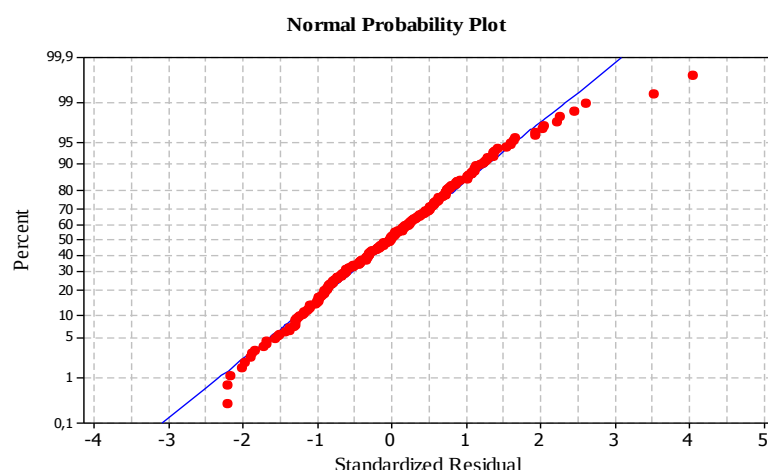


Figure 5.9. Normal probability plot for body mass (kg).

b. Independency Assumption: The anthropometric measurements as dependent variables are moderately correlated as shown in Figure 5.10. This assumption is met for subjects.

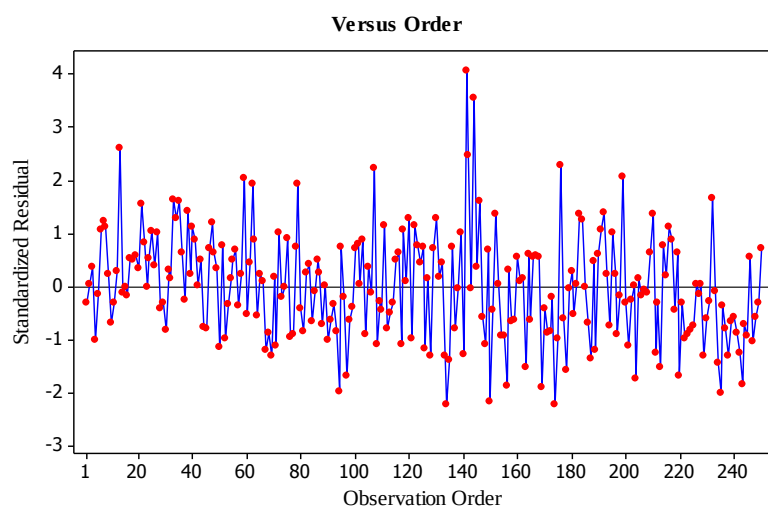


Figure 5.10. Plot of residuals versus observation order for subjects through body mass (kg).

Next, this assumption was checked for all other measurements, and it was seen that they as dependent variables are moderately correlated.

c. Homogeneity assumption: The last assumption about ANOVA is that variances of response variables for each treatment must not be different from each other (homogeneity assumption). Therefore, the residuals should be unrelated to any other variable including the predicted response. A simple check is to plot the residuals versus the fitted values.

These plots should not reveal any obvious pattern (Montgomery, 2005). Figure 5.11 shows the plot of the group variances versus fitted values. According to this figure, it is accepted that variances across groups are equal.

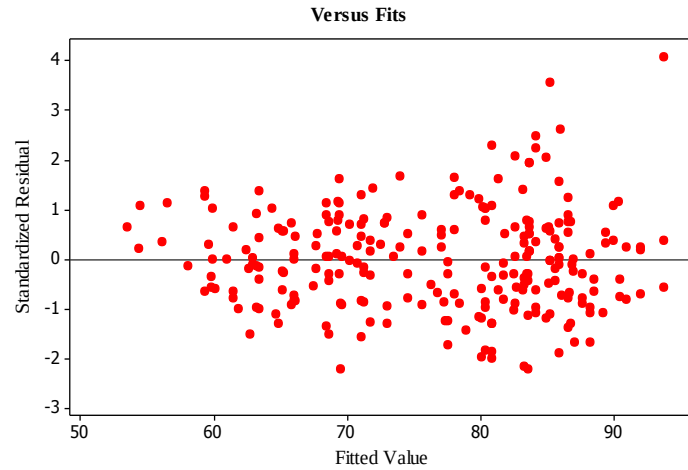


Figure 5.11. Equal variance probability plot for body mass (kg).

Although residual plots are frequently used to diagnose inequality of variance, when the normality assumption is satisfied, Bartlett's test may be viewed as a formal test of the hypotheses

$$\begin{aligned}
 H_0: \sigma_1^2 &= \sigma_2^2 = \dots = \sigma_n^2 \\
 H_1: \sigma_i^2 &\neq \sigma_j^2 \text{ for at least one pair } (i, j)
 \end{aligned}
 \tag{5.3}$$

where  $i$  and  $j$  shows the each one of anthropometric measurements ( $i \neq j$ ) and  $n$  equals to 65. In Bartlett's test, it is tested if the variances of the anthropometric measurements are equal.

According to the results of Bartlett's test for body mass, test statistic is 71.96; and also, p-value is 0.446 which is higher than 0.05. Therefore, the null hypothesis cannot be rejected. Next, this assumption was checked for all other measurements, and for subjects, variances are the same for each treatment in which the table of all results can be seen in the appendix part of this study.

According to the results of ANOVA, there is no interaction effect. Thus, the no-interaction statistical model used in this study can be stated as the following:

$$y_{ijk} = \mu + \alpha_i + \chi_j + \delta_k + \varepsilon_{ijk} \quad (5.4)$$

for

|                     |                                                                                                  |
|---------------------|--------------------------------------------------------------------------------------------------|
| $i = 1, 2, 3, 4, 5$ | (1: 18-29 years)<br>(2: 30-39 years)<br>(3: 40-49 years)<br>(4: 50-59 years)<br>(5: 60-70 years) |
| $j = 1, 2$          | (1: Non-manual workers)<br>(2: Manual workers)                                                   |
| $k = 1, 2,$         | (1: Normal people)<br>(2: Overweight people)                                                     |

where,

$y_{ijk}$ :  $ijk^{th}$  response (body dimension; e.g. body mass, stature)

$\mu$ : overall response mean

$\alpha_i$ : effect of  $i^{th}$  level for age-group factor (1:18-29; 2:30-39; 3:40-49; 4:50-59; 5:60-70).

$\chi_j$ : effect of  $j^{th}$  level for job-group factor (1:NM, 2:M)

$\delta_k$ : effect of  $k^{th}$  level for BMIP-group factor (excluded underweight people) (1:Normal weight, 2:Over weight)

$\varepsilon_{ijk}$ : NID  $(0, \sigma^2)$  random error component

The following tables show the significant factors affecting body mass and stature in normal position. Results in Table 5.11 indicate that job-group has a significant effect on body mass of subjects while age-group has a marginal effect on it. On the other hand, results in Table 5.12 indicate that age-group has a significant effect on stature while job-group does not significantly affect stature.

Table 5.11. Analysis of variance results for body mass of subjects.

| Source    | DF  | Seq SS  | Adj SS  | Adj MS | F value | P value |
|-----------|-----|---------|---------|--------|---------|---------|
| Age-group | 4   | 1312.5  | 1435.6  | 358.9  | 2.31    | 0.059   |
| Job-group | 1   | 1427.2  | 1427.2  | 1427.2 | 9.18    | 0.003   |
| Error     | 244 | 37914.9 | 37914.9 | 155.4  |         |         |
| Total     | 249 | 40654.6 |         |        |         |         |

Table 5.12. Analysis of variance results for stature of subjects.

| Source    | DF  | Seq SS   | Adj SS   | Adj MS | F value | P value |
|-----------|-----|----------|----------|--------|---------|---------|
| Age-group | 4   | 4021.64  | 3919.04  | 979.76 | 20.30   | <0.001  |
| Job-group | 1   | 29.61    | 29.61    | 29.61  | 0.61    | 0.434   |
| Error     | 244 | 11774.13 | 11774.13 | 48.25  |         |         |
| Total     | 249 | 15825.38 |          |        |         |         |

The ANOVA results including p-values in Table 5.13 indicate the effects of factors including BMIP-group, age-group and job-group on the other anthropometric measurements. In these analyses, underweight people were excluded since there were only 7 people in this BMIP-group and this is not enough to conclude accurate results.

Table 5.13. Summary of ANOVA results for other anthropometric measurements of subjects.\*

| Source     | DF  | Eye ht (n)     | Acr.(shld) ht (n) | Elbow ht (n) | Fngtip ht (n)  | Th-tip ht (n) | Fist ht (n)   | Waist ht (n) |
|------------|-----|----------------|-------------------|--------------|----------------|---------------|---------------|--------------|
| Age-group  | 4   | 16.52 (<0.001) | 13.69 (<0.001)    | 9.8 (<0.001) | 10.42 (<0.001) | 7.97 (<0.001) | 6.42 (<0.001) | 2.89 (0.023) |
| Job-group  | 1   | 0.83 (0.362)   | 0.32 (0.575)      | 0.05 (0.826) | 0.01 (0.912)   | 0.22 (0.640)  | 0 (0.953)     | 6.04 (0.015) |
| BMIP-group | 1   | 0.29 (0.589)   | 1.7 (0.193)       | 2.84 (0.093) | 2.73 (0.100)   | 3.23 (0.074)  | 1.34 (0.248)  | 0.29 (0.589) |
| Error      | 243 |                |                   |              |                |               |               |              |
| Total      | 249 |                |                   |              |                |               |               |              |

\* Numbers demonstrate F-value (p-value) in which the values in the first column indicates response values in the analysis of variance.

| Source     | DF  | Vertical grip rch | Vertical th-tip rch | Vertical fngtip rch | Forward grip rch | Forward th-tip rch | Forward fngtip rch | Span           | Elbow span    |
|------------|-----|-------------------|---------------------|---------------------|------------------|--------------------|--------------------|----------------|---------------|
| Age-group  | 4   | 15.07 (<0.001)    | 13.49 (<0.001)      | 13.9 (<0.001)       | 2.15 (0.075)     | 1.46 (0.215)       | 3.49 (0.009)       | 12.75 (<0.001) | 8.47 (<0.001) |
| Job-group  | 1   | 0.14 (0.710)      | 0.16 (0.692)        | 0.01 (0.927)        | 0.26 (0.611)     | 0.22 (0.642)       | 1.8 (0.181)        | 0.34 (0.559)   | 5.63 (0.018)  |
| BMIP-group | 1   | 1.12 (0.291)      | 1.33 (0.250)        | 0.94 (0.330)        | 0.39 (0.532)     | 0.02 (0.888)       | 0.43 (0.511)       | 0.24 (0.622)   | 2.45 (0.119)  |
| Error      | 243 |                   |                     |                     |                  |                    |                    |                |               |
| Total      | 249 |                   |                     |                     |                  |                    |                    |                |               |

| Source     | DF  | Chest depth    | Chest breadth  | Stand. e-to-e brt | Shld-elbow lgt | Shld-fngtip lgt | Shld-fist lgt | Foot length  | Foot breadth |
|------------|-----|----------------|----------------|-------------------|----------------|-----------------|---------------|--------------|--------------|
| Age-group  | 4   | 0.98 (0.421)   | 4.42 (0.002)   | 2.44 (0.047)      | 5.22 (<0.001)  | 6.92 (<0.001)   | 8.12 (<0.001) | 1.81 (0.128) | 1.02 (0.396) |
| Job-group  | 1   | 1.18 (0.279)   | 8.11 (0.005)   | 0.89 (0.346)      | 1.12 (0.290)   | 1.12 (0.291)    | 1.1 (0.296)   | 0.47 (0.492) | 3.55 (0.061) |
| BMIP-group | 1   | 54.01 (<0.001) | 61.19 (<0.001) | 46 (<0.001)       | 0.12 (0.731)   | 0.66 (0.418)    | 1.1 (0.295)   | 0.96 (0.328) | 3.53 (0.061) |
| Error      | 243 |                |                |                   |                |                 |               |              |              |
| Total      | 249 |                |                |                   |                |                 |               |              |              |

| Source     | DF  | Sit. ht (n)   | Sit. eye ht (n) | Sit. acr. (shld) ht (n) | Sit. elbow rest ht (n) | Knee ht        | Popliteal ht  | Buttock-knee lgt | Buttock-popliteal lgt |
|------------|-----|---------------|-----------------|-------------------------|------------------------|----------------|---------------|------------------|-----------------------|
| Age-group  | 4   | 7.56 (<0.001) | 7.19 (<0.001)   | 3.81 (0.005)            | 0.74 (0.563)           | 11.78 (<0.001) | 7.01 (<0.001) | 6.98 (<0.001)    | 4.86 (0.001)          |
| Job-group  | 1   | 8.72 (0.003)  | 9.38 (0.002)    | 0.04 (0.836)            | 2.16 (0.143)           | 0.35 (0.556)   | 0.99 (0.322)  | 3.24 (0.073)     | 2.34 (0.128)          |
| BMIP-group | 1   | 1.51 (0.220)  | 1.74 (0.189)    | 6.2 (0.013)             | 14.02 (<0.001)         | 3.62 (0.558)   | 0 (0.964)     | 12.59 (<0.001)   | 5.92 (0.016)          |
| Error      | 243 |               |                 |                         |                        |                |               |                  |                       |
| Total      | 249 |               |                 |                         |                        |                |               |                  |                       |

| Source     | DF  | Thigh clearance | Buttock-leg lgt | Sit.vertical grip rch | Sit.vertical th-tip rch | Sit.vertical fngtip rch | Sit.forward grip rch | Sit. forward grip rch | Sit.forward fngtip rch |
|------------|-----|-----------------|-----------------|-----------------------|-------------------------|-------------------------|----------------------|-----------------------|------------------------|
| Age-group  | 4   | 3.09 (0.017)    | 10 (<0.001)     | 13.24 (<0.001)        | 12.73 (<0.001)          | 13.36 (<0.001)          | 3.08 (0.017)         | 3.17 (0.015)          | 4.58 (0.001)           |
| Job-group  | 1   | 0.01 (0.923)    | 0 (0.992)       | 1.17 (0.281)          | 1.8 (0.181)             | 2.11 (0.148)            | 4.57 (0.034)         | 3.05 (0.082)          | 9.57 (0.002)           |
| BMIP-group | 1   | 48.01 (<0.001)  | 4.02 (0.046)    | 1.06 (0.303)          | 2.67 (0.104)            | 2.81 (0.095)            | 0.24 (0.623)         | 0.4 (0.528)           | 0.63 (0.430)           |
| Error      | 243 |                 |                 |                       |                         |                         |                      |                       |                        |
| Total      | 249 |                 |                 |                       |                         |                         |                      |                       |                        |

Table 5.13. Summary of ANOVA results for other anthropometric measurements of subjects (cont'd).

[illegible][illegible]

ANOVA results in Table 5.11, Table 5.12 and Table 5.13 can be summarized as follows:

- Age-group has a marginal effect on body mass whereas job-group significantly affects it.
- Age-group has a significant effect on stature.
- Age-group significantly affects all of the vertical anthropometric measurements.
- Age-group does not have an effect on hand measurements except wrist circumference.
- Age-group was found significant for almost all measurement related to face except menton-sellion (face) length.
- Sitting height and buttock-knee length are affected by both age-group and job-group.
- Shoulder breadth values are affected by job-groups and BMIP-groups.
- There is no factor affecting foot length and menton-sellion (face) length.
- BMIP has a significant effect on elbow-to-elbow breadth.
- All head measurements including head length, head breadth, head and neck circumference are significantly affected by BMIP-group.
- There are significant effects of age-group and BMIP-group on measurement of waist circumference.

#### **5.2.4. Post-Hoc Analysis**

For multiple comparisons, Tukey's test was used. For Tukey's test, anthropometric measurements which were measured in both erect and normal positions were analyzed for only their values in the latter because of the fact that people are usually in their normal positions while working. Also, while checking the Tukey's test results, Table 5.11, Table 5.12 and Table 5.13 were used. Then, the factors which affect an anthropometric dimension were analyzed by using Tukey's test in the following tables.

According to the results in Table 5.14, body mass is highest in age group (30-39) and lowest in age group (60-70); also, the difference between age groups are not significant.

In Table 5.15, Tukey's test results stratified by age-groups indicate that body mass of subjects is higher in non-manual workers. The differences between groups were found to be significant.

Table 5.14. Tukey's test results for age-group differences in body mass.

| Age Group Difference | Difference of Means | CI for Means      | Standard Error | P -value |
|----------------------|---------------------|-------------------|----------------|----------|
| (18-29)-(30-39)      | -4.35               | (-11.20) - (2.51) | 2.51           | 0.41     |
| (18-29)-(40-49)      | -2.24               | (-9.03) - (4.54)  | 2.49           | 0.90     |
| (18-29)-(50-59)      | -1.23               | (-7.98) - (5.52)  | 2.47           | 0.99     |
| (18-29)-(60-70)      | 2.74                | (-4.27) - (9.75)  | 2.57           | 0.82     |
| (30-39)-(40-49)      | 2.10                | (-4.82) - (9.02)  | 2.54           | 0.92     |
| (30-39)-(50-59)      | 3.12                | (-3.77) - (10.00) | 2.52           | 0.73     |
| (30-39)-(60-70)      | 7.09                | (-0.05) - (14.23) | 2.62           | 0.06     |
| (40-49)-(50-59)      | 1.01                | (-5.80) - (7.83)  | 2.50           | 0.99     |
| (40-49)-(60-70)      | 4.99                | (-2.89) - (12.06) | 2.59           | 0.30     |
| (50-59)-(60-70)      | 3.97                | (-3.07) - (11.01) | 2.58           | 0.54     |

Table 5.15. Tukey's test results for job-group differences in body mass.

| Job Group Difference  | Difference of Means | CI for Means    | Standard Error | P -value |
|-----------------------|---------------------|-----------------|----------------|----------|
| (Non-manual)-(Manual) | 4.57                | (1.43) - (7.71) | 1.59           | 0.004    |

For stature in normal position, age-group was taken into account for Tukey's test since only it had a significant effect according to the results of analysis of variance in Table 5.13. Stature in normal position was found as highest in age group (18-29) and lowest in age group (60-70). The results of Tukey's test support this fact as given in Table 5.16.

Next, the following tables demonstrate Tukey's test results for some anthropometric measurements. For the results of other dimensions, the tables refer to Appendix part of this study.

Table 5.16. Tukey's test results for age-group differences in stature (normal).

| Age-Group Difference | Difference of Means | CI for Means     | Standard Error | P -value |
|----------------------|---------------------|------------------|----------------|----------|
| (18-29)-(30-39)      | 1.87                | (-1.88) - (5.63) | 1.38           | 0.653    |
| (18-29)-(40-49)      | 5.16                | (1.44) - (8.87)  | 1.36           | 0.001    |
| (18-29)-(50-59)      | 8.04                | (4.35) - (11.74) | 1.36           | <0.001   |
| (18-29)-(60-70)      | 11.21               | (7.37) - (15.35) | 1.41           | <0.001   |
| (30-39)-(40-49)      | 3.29                | (-0.50) - (7.08) | 1.39           | 0.124    |
| (30-39)-(50-59)      | 6.17                | (2.40) - (9.95)  | 1.38           | <0.001   |
| (30-39)-(60-70)      | 9.34                | (5.43) - (13.25) | 1.43           | <0.001   |
| (40-49)-(50-59)      | 2.89                | (-0.85) - (6.62) | 1.37           | 0.216    |
| (40-49)-(60-70)      | 6.06                | (2.18) - (9.93)  | 1.42           | <0.001   |
| (50-59)-(60-70)      | 3.17                | (-0.69) - (7.03) | 1.41           | 0.165    |

Table 5.17. Tukey's test results for age-group differences in acromial shoulder ht(normal).

| Age Group Difference | Difference of Means | CI for Means     | Standard Error | P -value |
|----------------------|---------------------|------------------|----------------|----------|
| (18-29)-(30-39)      | -0.62               | (-4.12) - (2.88) | 1.28           | 0.989    |
| (18-29)-(40-49)      | 3.16                | (-0.30) - (6.63) | 1.27           | 0.092    |
| (18-29)-(50-59)      | 5.65                | (2.20) - (9.09)  | 1.27           | <0.001   |
| (18-29)-(60-70)      | 7.42                | (3.84) - (11.00) | 1.31           | <0.001   |
| (30-39)-(40-49)      | 3.79                | (0.25) - (7.32)  | 1.29           | 0.028    |
| (30-39)-(50-59)      | 6.27                | (2.75) - (9.78)  | 1.29           | <0.001   |
| (30-39)-(60-70)      | 8.05                | (4.40) - (11.69) | 1.34           | <0.001   |
| (40-49)-(50-59)      | 2.48                | (-1.00) - 5.96)  | 1.28           | 0.293    |
| (40-49)-(60-70)      | 4.26                | (0.65) - (7.87)  | 1.32           | 0.011    |
| (50-59)-(60-70)      | 1.78                | (-1.82) - (5.38) | 1.32           | 0.660    |

Table 5.18. Tukey's test results for age-group differences in vertical fingertip reach.

| Age Group Difference | Difference of Means | CI for Means      | Standard Error | P -value |
|----------------------|---------------------|-------------------|----------------|----------|
| (18-29)-(30-39)      | 2.67                | (-2.92) - (8.26)  | 2.05           | 0.680    |
| (18-29)-(40-49)      | 7.70                | (2.17) - (13.23)  | 2.03           | 0.001    |
| (18-29)-(50-59)      | 12.04               | (6.54) - (17.54)  | 2.02           | <0.001   |
| (18-29)-(60-70)      | 13.18               | (7.47) - (18.90)  | 2.09           | <0.001   |
| (30-39)-(40-49)      | 5.03                | (-0.61) - (10.67) | 2.07           | 0.106    |
| (30-39)-(50-59)      | 9.37                | (3.76) - (14.98)  | 2.06           | <0.001   |
| (30-39)-(60-70)      | 10.51               | (4.69) - (16.33)  | 2.13           | <0.001   |
| (40-49)-(50-59)      | 4.34                | (-1.21) - (9.89)  | 2.04           | 0.206    |
| (40-49)-(60-70)      | 5.48                | (-0.28) - (11.25) | 2.11           | 0.071    |
| (50-59)-(60-70)      | 1.14                | (-4.60) - (6.88)  | 2.10           | 0.983    |

Table 5.19. Tukey's test results for age-group differences in span.

| Age Group Difference | Difference of Means | CI for Means     | Standard Error | P -value |
|----------------------|---------------------|------------------|----------------|----------|
| (18-29)-(30-39)      | 0.52                | (-3.68) - (4.71) | 1.54           | 0.997    |
| (18-29)-(40-49)      | 3.65                | (-0.51) - (7.80) | 1.52           | 0.116    |
| (18-29)-(50-59)      | 7.08                | (2.94) - (11.21) | 1.51           | <0.001   |
| (18-29)-(60-70)      | 9.96                | (5.66) - (14.25) | 1.57           | <0.001   |
| (30-39)-(40-49)      | 3.13                | (-1.10) - (7.37) | 1.55           | 0.257    |
| (30-39)-(50-59)      | 6.56                | (2.35) - (10.78) | 1.55           | <0.001   |
| (30-39)-(60-70)      | 9.44                | (5.07) - (13.81) | 1.60           | <0.001   |
| (40-49)-(50-59)      | 3.43                | (-0.75) - (7.60) | 1.53           | 0.165    |
| (40-49)-(60-70)      | 6.31                | (1.98) - (10.64) | 1.59           | <0.001   |
| (50-59)-(60-70)      | 2.88                | (-1.43) - (7.19) | 1.58           | 0.361    |

Table 5.20. Tukey's test results for age-group differences in sit.height (normal).

| Age Group Difference | Difference of Means | CI for Means     | Standard Error | P -value |
|----------------------|---------------------|------------------|----------------|----------|
| (18-29)-(30-39)      | 0.62                | (-1.36) - (2.59) | 0.72           | 0.915    |
| (18-29)-(40-49)      | 1.35                | (-0.61) - (3.31) | 0.72           | 0.326    |
| (18-29)-(50-59)      | 3.09                | (1.14) - (5.03)  | 0.71           | <0.001   |
| (18-29)-(60-70)      | 3.22                | (1.19) - (5.24)  | 0.74           | <0.001   |
| (30-39)-(40-49)      | 0.73                | (-1.26) - (2.73) | 0.73           | 0.854    |
| (30-39)-(50-59)      | 2.47                | (0.48) - (4.46)  | 0.73           | 0.006    |
| (30-39)-(60-70)      | 2.60                | (0.54) - (4.66)  | 0.75           | 0.005    |
| (40-49)-(50-59)      | 1.73                | (-0.23) - (3.70) | 0.72           | 0.113    |
| (40-49)-(60-70)      | 1.86                | (-0.18) - (3.90) | 0.75           | 0.092    |
| (50-59)-(60-70)      | 0.13                | (-1.90) - (2.16) | 0.74           | 1.000    |

Table 5.21. Tukey's test results for job-group differences in sit. ht (normal).

| Job Group Difference  | Difference of Means | CI for Means    | Standard Error | P -value |
|-----------------------|---------------------|-----------------|----------------|----------|
| (Non-manual)-(Manual) | 1.47                | (0.52) - (2.41) | 0.48           | 0.002    |

Table 5.22. Tukey's test results for age-group differences in sit.acromial shoulderht (n).

| Age Group Difference | Difference of Means | CI for Means     | Standard Error | P -value |
|----------------------|---------------------|------------------|----------------|----------|
| (18-29)-(30-39)      | 0.21                | (-1.87) - (2.28) | 0.76           | 0.999    |
| (18-29)-(40-49)      | 1.29                | (-0.76) - (3.34) | 0.75           | 0.426    |
| (18-29)-(50-59)      | 1.47                | (-0.58) - (3.51) | 0.75           | 0.287    |
| (18-29)-(60-70)      | 2.05                | (-0.07) - (4.18) | 0.78           | 0.063    |
| (30-39)-(40-49)      | 1.08                | (-1.01) - (3.18) | 0.77           | 0.621    |
| (30-39)-(50-59)      | 1.26                | (-0.82) - (3.34) | 0.76           | 0.466    |
| (30-39)-(60-70)      | 1.85                | (-0.31) - (4.01) | 0.79           | 0.135    |
| (40-49)-(50-59)      | 0.18                | (-1.89) - (2.24) | 0.76           | 0.999    |
| (40-49)-(60-70)      | 0.76                | (-1.38) - (2.91) | 0.78           | 0.867    |
| (50-59)-(60-70)      | 0.59                | (-1.54) - (2.72) | 0.78           | 0.944    |

Table 5.23. Tukey's test results for BMIP-group differences in sit.acromial shoulder ht (n).

| BMIP Group Difference        | Difference of Means | CI for Means     | Standard Error | P -value |
|------------------------------|---------------------|------------------|----------------|----------|
| (Normal weight)-(Overweight) | 0.85                | (-2.03) - (0.34) | 0.506          | 0.094    |

Table 5.24. Tukey's test results for age-group differences in buttock-leg length.

| Age Group Difference | Difference of Means | CI for Means     | Standard Error | P -value |
|----------------------|---------------------|------------------|----------------|----------|
| (18-29)-(30-39)      | 1.36                | (-1.39) - (4.11) | 1.01           | 0.659    |
| (18-29)-(40-49)      | 2.74                | (0.02) - (5.45)  | 0.10           | 0.048    |
| (18-29)-(50-59)      | 4.24                | (1.53) - (6.94)  | 0.99           | <0.001   |
| (18-29)-(60-70)      | 5.58                | (2.77) - (8.39)  | 0.99           | <0.001   |
| (30-39)-(40-49)      | 1.37                | (-1.40) - (4.15) | 1.02           | 0.659    |
| (30-39)-(50-59)      | 2.88                | (0.12) - (5.64)  | 1.01           | 0.036    |
| (30-39)-(60-70)      | 4.22                | (1.36) - (7.09)  | 1.05           | <0.001   |
| (40-49)-(50-59)      | 1.50                | (-1.23) - (4.24) | 1.00           | 0.561    |
| (40-49)-(60-70)      | 2.85                | (0.01) - (5.68)  | 1.04           | 0.048    |
| (50-59)-(60-70)      | 1.35                | (-1.48) - (4.17) | 1.03           | 0.691    |

Table 5.25. Tukey's test results for BMIP differences in buttock-leg length.

| BMIP Group Difference       | Difference of Means | CI for Means     | Standard Error | P -value |
|-----------------------------|---------------------|------------------|----------------|----------|
| (Normalweight)-(Overweight) | -0.45               | (-2.10) - (1.21) | 0.71           | 0.530    |

Table 5.26. Tukey's test results for job-group differences in chest (bust) breadth.

| Job Group Difference  | Difference of Means | CI for Means    | Standard Error | P -value |
|-----------------------|---------------------|-----------------|----------------|----------|
| (Non-manual)-(Manual) | 1.11                | (0.40) - (1.82) | 0.36           | 0.002    |

Table 5.27. Tukey's test results for BMIP differences in chest (bust) breadth.

| BMIP Group Difference       | Difference of Means | CI for Means      | Standard Error | P -value |
|-----------------------------|---------------------|-------------------|----------------|----------|
| (Normalweight)-(Overweight) | -2.44               | (-3.25) - (-1.63) | 0.35           | <0.001   |

Table 5.28. Tukey's test results for age-group differences in head circumference.

| Age Group Difference | Difference of Means | CI for Means     | Standard Error | P -value |
|----------------------|---------------------|------------------|----------------|----------|
| (18-29)-(30-39)      | 0.88                | (-0.21) - (1.98) | 0.40           | 0.180    |
| (18-29)-(40-49)      | 1.31                | (0.22) - (2.39)  | 0.40           | 0.009    |
| (18-29)-(50-59)      | 1.33                | (0.25) - (2.41)  | 0.40           | 0.007    |
| (18-29)-(60-70)      | 1.55                | (0.43) - (2.67)  | 0.41           | 0.002    |
| (30-39)-(40-49)      | 0.43                | (-0.68) - (1.53) | 0.41           | 0.833    |
| (30-39)-(50-59)      | 0.44                | (-0.66) - (1.54) | 0.40           | 0.809    |
| (30-39)-(60-70)      | 0.67                | (-0.47) - (1.81) | 0.42           | 0.500    |
| (40-49)-(50-59)      | 0.02                | (-1.07) - (1.11) | 0.40           | 1.000    |
| (40-49)-(60-70)      | 0.24                | (-0.89) - (1.38) | 0.41           | 0.977    |
| (50-59)-(60-70)      | 0.23                | (-0.90) - (1.35) | 0.41           | 0.982    |

Table 5.29. Tukey's test results for BMIP-group differences in head circumference.

| BMIP Group Difference        | Difference of Means | CI for Means    | Standard Error | P -value |
|------------------------------|---------------------|-----------------|----------------|----------|
| (Normal weight)-(Overweight) | 0.73                | (-1.37)-(-0.10) | 0.27           | 0.006    |

Table 5.30. Tukey's test results for age-group differences in waist circumference.

| Age Group Difference | Difference of Means | CI for Means       | Standard Error | P -value |
|----------------------|---------------------|--------------------|----------------|----------|
| (18-29)-(30-39)      | -5,34               | (-10.90) - (0.23)  | 2.04           | 0.068    |
| (18-29)-(40-49)      | -6.02               | (-11.53) - (-0.51) | 2.02           | 0.024    |
| (18-29)-(50-59)      | -6.37               | (-11.85) - (-0.89) | 2.01           | 0.013    |
| (18-29)-(60-70)      | -7.63               | (-13.32) - (-1.93) | 2.09           | 0.002    |
| (30-39)-(40-49)      | -0.69               | (-6.31) - (4.94)   | 2.06           | 0.997    |
| (30-39)-(50-59)      | -1.04               | (-6.63) - (4.56)   | 2.05           | 0.987    |
| (30-39)-(60-70)      | -2.29               | (-8.09) - (3.51)   | 2.13           | 0.818    |
| (40-49)-(50-59)      | -0.35               | (-5.89) - (5.19)   | 2.03           | 1.000    |
| (40-49)-(60-70)      | -1.61               | (-7.35) - (4.14)   | 2.11           | 0.941    |
| (50-59)-(60-70)      | -1.26               | (-6.98) - (4.46)   | 2.10           | 0.975    |

According to the results of Tukey's tests, the following comments can be given:

- People at their 30s are the heaviest while those at their 60s are the lightest.
- Non-manual workers are heavier than manual workers.
- People at their 20s are the tallest and have the bigger dimensions in almost all vertical measurements. Then, these measurements are decreasing with aging.
- Age has a significant effect on buttock-leg length measurement, and the youngest group (18-29 years) has the largest value for this dimension.
- For older ages, waist circumference is increasing, and people at their 60s has the largest values for the measurement of waist circumference
- Normal weight group has significantly larger head circumference compared to over weight group.

### 5.2.5. Regression Analysis

5.2.5.1. Checking the Regression Assumptions. The fulfillment of assumptions is checked before applying the regression analysis. Some of these assumptions checked for ANOVA were the same. The results indicate that there are not significant violations of assumption, therefore it can be said that the regression analysis with the used variables is valid.

5.2.5.2. Regression Equation of Anthropometric Measurements. In this study, Minitab 16.0 was used in order to investigate type of relations between dimensions and regressor variables. According to the results of this statistical analysis, there is no quadratic term for anthropometric measurements, and all relations were found as linear. Thus, the general form of the regression model is obtained given in the following equation:

For each of the anthropometric measurement, the results of ANOVA and correlation analysis were used for developing prediction equations. When applying regression, every independent variable including age-group and job-group was taken into consideration. Also, the values of body mass and stature in normal position were used for regression instead of BMIP-group in order to have higher  $R^2_{adj}$  values. In these models, only main effects of factors were only considered. Moreover, the interaction effects between factors and quadratic terms were neglected. After having results by these models including independent variables, some trials for regression models were done to have the maximum  $R^2_{adj}$  value. While trying to maximize this value in regression equation, Stepwise Regression and Best Subsets Regression Analysis methods were used. Interaction effects were neglected in both techniques and only the main effects were taken into consideration. Also, as a last analysis, some regression equations including only stature as regressor variable were obtained.

Best subsets regression identifies the subset models that produce the highest  $R^2_{adj}$  values from full set of the predictor variables specified. Best subsets regression is an efficient way to identify models through the goals with as few predictors as possible. Subset models may actually estimate the regression coefficients and predict future responses with smaller variance than the full model using all predictors. In best subsets technique, a statistic (Mallows' Cp) was used as an aid in choosing between multiple

regression models. It compares the precision and bias of the full model to models with the best subsets of predictors. A model with too many predictors can be relatively imprecise while one with too few can produce biased estimates. The best model is the minimizer of  $C_p$  in the existence of the highest  $R_{adj}^2$  value.

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \varepsilon \quad (5.5)$$

where

$y$ : Response variable (e.g. span, foot length or hand length)

$\beta_0$ : Constant

$\beta_1$ : Regression coefficient of age

$\beta_2$ : Regression coefficient of job-group

$\beta_3$ : Regression coefficient of body mass

$\beta_4$ : Regression coefficient of stature in normal position

$x_1$ : Regressor variable of age

$x_2$ : Regressor variable of job-group (1 for non-manual workers or 2 for manual workers)

$x_3$ : Regressor variable of body mass

$x_4$ : Regressor variable of stature in normal position

$\varepsilon$ : Error term ( $\varepsilon \sim \text{NID}(0, \sigma^2)$ )

In regression equation, the interaction effects between factors and quadratic terms were neglected in general linear models because p-values of them by 0.005 were less than significance level. The regression equations of some anthropometric measurements including acromial (shoulder) height in standing posture, vertical fingertip reach, span, chest (bust) breadth, shoulder-fingertip length, foot length, sitting height (normal), buttock-leg length, head circumference, waist circumference and hand length are given as follows;

Table 5.31. Regression analysis results of acromial (shoulder) height in standing posture.

| Predictor | Coefficient | SE Coefficient | T     | P       | VIF  |
|-----------|-------------|----------------|-------|---------|------|
| Constant  | 9.94        | 6.40           | 1.55  | 0.121   |      |
| Age       | -0.01       | 0.02           | -0.02 | 0.984   | 1.39 |
| Job-Gorup | 0.55        | 0.47           | 1.17  | 0.242   | 1.04 |
| Body Mas  | 0.04        | 0.02           | 1.78  | 0.076   | 1.28 |
| Stature   | 0.75        | 0.04           | 20.03 | < 0.001 | 1.66 |

Table 5.32. Regression analysis results of vertical fingertip reach.

| Predictor | Coefficient | SE Coefficient | T     | P       | VIF  |
|-----------|-------------|----------------|-------|---------|------|
| Constant  | 46.99       | 13.59          | 3.46  | 0.001   |      |
| Age       | -0.08       | 0.04           | -1.91 | 0.058   | 1.39 |
| Job-Gorup | 0.84        | 1.00           | 0.84  | 0.399   | 1.07 |
| Body Mas  | 0.01        | 0.04           | 0.19  | 0.847   | 1.21 |
| Stature   | 0.99        | 0.08           | 12.51 | < 0.001 | 1.57 |

Table 5.33. Regression analysis results of span.

| Predictor | Coefficient | SE Coefficient | T     | P       | VIF  |
|-----------|-------------|----------------|-------|---------|------|
| Constant  | -1.03       | 5.86           | -0.18 | 0.861   |      |
| Age       | 0.02        | 0.02           | 1.28  | 0.202   | 1.19 |
| Job-Gorup | 0.61        | 0.43           | 1.42  | 0.158   | 1.08 |
| Body Mas  | 0.03        | 0.02           | 1.63  | 0.104   | 1.28 |
| Stature   | 0.99        | 0.03           | 29.09 | < 0.001 | 1.46 |

Table 5.34. Regression analysis results of chest (bust) breadth.

| Predictor | Coefficient | SE Coefficient | T     | P       | VIF  |
|-----------|-------------|----------------|-------|---------|------|
| Constant  | 14.18       | 3.84           | 3.70  | < 0.001 |      |
| Age       | -0.01       | 0.01           | -0.52 | 0.600   | 1.39 |
| Job-Gorup | -0.43       | 0.28           | -1.52 | 0.129   | 1.04 |
| Body Mas  | 0.13        | 0.01           | 10.89 | < 0.001 | 1.28 |
| Stature   | 0.04        | 0.02           | 1.81  | 0.072   | 1.62 |

Table 5.35. Regression analysis results of shoulder-fingertip length.

| Predictor | Coefficient | SE Coefficient | T     | P       | VIF  |
|-----------|-------------|----------------|-------|---------|------|
| Constant  | -15.20      | 6.19           | -2.46 | 0.015   |      |
| Age       | 0.05        | 0.02           | 2.32  | 0.021   | 1.39 |
| Job-Gorup | 0.07        | 0.45           | 0.16  | 0.874   | 1.28 |
| Body Mas  | -0.01       | 0.02           | -0.20 | 0.838   | 1.28 |
| Stature   | 0.54        | 0.04           | 15.00 | < 0.001 | 1.66 |

Table 5.36. Regression analysis results of foot length.

| Predictor | Coefficient | SE Coefficient | T    | P       | VIF  |
|-----------|-------------|----------------|------|---------|------|
| Constant  | 5.18        | 2.20           | 2.35 | 0.020   |      |
| Age       | -0.02       | 0.01           | 2.22 | 0.027   | 1.38 |
| Job-Gorup | 0.03        | 0.16           | 0.20 | 0.838   | 1.04 |
| Body Mas  | 0.01        | 0.01           | 1.58 | 0.116   | 1.24 |
| Stature   | 0.11        | 0.01           | 8.57 | < 0.001 | 1.56 |

Table 5.37. Regression analysis results of sitting height (normal).

| Predictor | Coefficient | SE Coefficient | T     | P       | VIF  |
|-----------|-------------|----------------|-------|---------|------|
| Constant  | 50.45       | 5.53           | 9.12  | < 0.001 |      |
| Age       | -0.02       | 0.02           | -1.16 | 0.245   | 1.38 |
| Job-Gorup | -0.96       | 0.41           | -2.37 | 0.018   | 1.04 |
| Body Mas  | 0.03        | 0.02           | 1.43  | 0.153   | 1.28 |
| Stature   | 0.23        | 0.03           | 7.22  | < 0.001 | 1.62 |

Table 5.38. Regression analysis results of buttock-leg length.

| Predictor | Coefficient | SE Coefficient | T     | P       | VIF  |
|-----------|-------------|----------------|-------|---------|------|
| Constant  | 26.26       | 6.55           | 4.01  | < 0.001 |      |
| Age       | -0.01       | 0.03           | -0.67 | 0.504   | 1.38 |
| Job-Gorup | 0.40        | 0.48           | 0.84  | 0.402   | 1.05 |
| Body Mas  | 0.07        | 0.02           | 3.40  | 0.001   | 1.28 |
| Stature   | 0.43        | 0.04           | 11.22 | < 0.001 | 1.69 |

Table 5.39. Regression analysis results of head circumference.

| Predictor | Coefficient | SE Coefficient | T     | P       | VIF  |
|-----------|-------------|----------------|-------|---------|------|
| Constant  | 45.70       | 3.33           | 13.71 | < 0.001 |      |
| Age       | -0.01       | 0.01           | -1.72 | 0.086   | 1.39 |
| Job-Gorup | -0.21       | 0.24           | -0.87 | 0.388   | 1.04 |
| Body Mas  | 0.04        | 0.01           | 3.58  | < 0.001 | 1.24 |
| Stature   | 0.05        | 0.02           | 2.77  | 0.006   | 1.65 |

Table 5.40. Regression analysis results of waist circumference.

| Predictor | Coefficient | SE Coefficient | T     | P       | VIF  |
|-----------|-------------|----------------|-------|---------|------|
| Constant  | 63.58       | 12.79          | 4.97  | < 0.001 |      |
| Age       | 0.16        | 0.04           | 4.02  | < 0.001 | 1.38 |
| Job-Gorup | 1.34        | 0.94           | 1.43  | 0.153   | 1.02 |
| Body Mas  | 0.62        | 0.04           | 15.15 | < 0.001 | 1.26 |
| Stature   | -0.17       | 0.07           | -2.33 | 0.021   | 1.61 |

Table 5.41. Regression analysis results of hand length.

| Predictor | Coefficient | SE Coefficient | T     | P       | VIF  |
|-----------|-------------|----------------|-------|---------|------|
| Constant  | 3.09        | 1.77           | 1.75  | 0.082   |      |
| Age       | 0.02        | 0.01           | 2.83  | 0.005   | 1.37 |
| Job-Gorup | -0.02       | 0.13           | -0.12 | 0.902   | 1.03 |
| Body Mas  | 0.01        | 0.01           | 1.44  | 0.152   | 1.28 |
| Stature   | 0.08        | 0.01           | 8.19  | < 0.001 | 1.65 |

A test for significance of regression is performed to determine whether a linear relationship exists between the response variable and a subset of the regressor variables  $x_1, x_2, \dots, x_n$  (Montgomery, 2005). The appropriate hypotheses are,

$$\begin{aligned}
 H_0: \beta_1 = \beta_2 = \beta_3 = \beta_4 = 0 \\
 H_1: \beta_j \neq 0 \text{ for at least one } j
 \end{aligned}
 \tag{5.6}$$

Rejection of  $H_0$  in Equation 5.6 implies that at least one of the regressor variables contributes significantly to the model. To test this significance, an ANOVA table is used which takes into consideration total sum of squares, sum of squares due to regression model and sum of squares due to residual. If the p-value for the statistic F is less than

significance level, the null hypothesis  $H_0$  is rejected, which implies that at least one of the regressor variables contributes significantly to the model (Montgomery, 2005).

The following tables demonstrate analysis of variance results of regression model for some anthropometric measurements. At least one of the regressor variables contributes significantly to the model ( $p < 0.05$ ).

Table 5.42. Analysis of variance table of regression model for acromial (shoulder) height (normal) in standing posture.

| Source         | DF  | SS       | MS      | F      | P       |
|----------------|-----|----------|---------|--------|---------|
| Regression     | 4   | 9386.80  | 2346.70 | 177.55 | < 0.001 |
| Residual Error | 245 | 3238.30  | 13.22   |        |         |
| Total          | 249 | 12625.10 |         |        |         |

Table 5.43. Analysis of variance table of regression model for vertical fingertip reach.

| Source         | DF  | SS       | MS      | F     | P       |
|----------------|-----|----------|---------|-------|---------|
| Regression     | 4   | 18075.30 | 4518.83 | 75.69 | < 0.001 |
| Residual Error | 245 | 14627.20 | 59.70   |       |         |
| Total          | 249 | 32702.50 |         |       |         |

Table 5.44. Analysis of variance table of regression model for span.

| Source         | DF  | SS       | MS      | F      | P       |
|----------------|-----|----------|---------|--------|---------|
| Regression     | 4   | 15568.20 | 3892.04 | 351.13 | < 0.001 |
| Residual Error | 245 | 2715.70  | 11.08   |        |         |
| Total          | 249 | 18283.90 |         |        |         |

Table 5.45. Analysis of variance table of regression model for chest (bust) breadth.

| Source         | DF  | SS      | MS     | F     | P       |
|----------------|-----|---------|--------|-------|---------|
| Regression     | 4   | 926.47  | 231.62 | 48.76 | < 0.001 |
| Residual Error | 245 | 1163.78 | 4.75   |       |         |
| Total          | 249 | 2090.25 |        |       |         |

Table 5.46. Analysis of variance table of regression model for shoulder-fingertip length.

| Source         | DF  | SS      | MS      | F     | P       |
|----------------|-----|---------|---------|-------|---------|
| Regression     | 4   | 4009.43 | 1002.36 | 81.02 | < 0.001 |
| Residual Error | 245 | 3031.11 | 12.37   |       |         |
| Total          | 249 | 7040.54 |         |       |         |

Table 5.47. Analysis of variance table of regression model for foot length.

| Source         | DF  | SS     | MS    | F     | P       |
|----------------|-----|--------|-------|-------|---------|
| Regression     | 4   | 185.75 | 46.44 | 25.58 | < 0.001 |
| Residual Error | 245 | 384.62 | 1.57  |       |         |
| Total          | 249 | 570.37 |       |       |         |

Table 5.48. Analysis of variance table of regression model for sitting height (normal).

| Source         | DF  | SS      | MS     | F     | P       |
|----------------|-----|---------|--------|-------|---------|
| Regression     | 4   | 1272.75 | 318.19 | 32.22 | < 0.001 |
| Residual Error | 245 | 2419.49 | 9.88   |       |         |
| Total          | 249 | 3692.24 |        |       |         |

Table 5.49. Analysis of variance table of regression model for buttock-leg length.

| Source         | DF  | SS      | MS     | F     | P       |
|----------------|-----|---------|--------|-------|---------|
| Regression     | 4   | 3893.38 | 973.35 | 70.18 | < 0.001 |
| Residual Error | 245 | 3398.10 | 13.87  |       |         |
| Total          | 249 | 7291.48 |        |       |         |

Table 5.50. Analysis of variance table of regression model for head circumference.

| Source         | DF  | SS      | MS    | F     | P       |
|----------------|-----|---------|-------|-------|---------|
| Regression     | 4   | 204.58  | 51.14 | 14.24 | < 0.001 |
| Residual Error | 245 | 879.62  | 3.59  |       |         |
| Total          | 249 | 1084.20 |       |       |         |

Table 5.51. Analysis of variance table of regression model for waist circumference.

| Source         | DF  | SS       | MS      | F     | P       |
|----------------|-----|----------|---------|-------|---------|
| Regression     | 4   | 14806.80 | 3701.70 | 70.04 | < 0.001 |
| Residual Error | 245 | 12948.90 | 52.90   |       |         |
| Total          | 249 | 27755.70 |         |       |         |

Table 5.52. Analysis of variance table of regression model for hand length.

| Source         | DF  | SS     | MS    | F     | P       |
|----------------|-----|--------|-------|-------|---------|
| Regression     | 4   | 104.42 | 26.10 | 25.90 | < 0.001 |
| Residual Error | 245 | 246.96 | 1.01  |       |         |
| Total          | 249 | 351.38 |       |       |         |

Variance inflation factor (VIF) indicates the extent to which multicollinearity refers to predictors that are correlated with other predictors is present in a regression analysis. Moderate multicollinearity may not be problematic. However, severe multicollinearity is problematic because it can increase the variance of the regression coefficients, making them unstable and difficult to interpret. Variance inflation factors (VIF) measure how much the variance of the estimated regression coefficients are inflated as compared to when the predictor variables are not linearly related. If  $VIF = 1$  predictors are not correlated. If  $1 < VIF < 5$ , predictors are moderately correlated. If  $5 < VIF < 10$ , predictors are highly correlated. VIF values greater than 10 may indicate multicollinearity is unduly influencing regression results (Kalaycı, 2006). In this study, VIF values smaller than 5 were taken into consideration in order to prevent multicollinearity. Also, multicollinearity

can be reduced by removing variables which are highly correlated to each others from the model. Because they supply redundant information, removing them often does not drastically reduce the  $R^2_{adj}$  value.

Regression equations with the variables including age, job-group, body mass and stature for some anthropometric measurements, and also regression models with some other independent variables which provide maximum  $R^2_{adj}$  value that were obtained by the results of both stepwise and best subset methods for subjects are given in Table 5.53 and Table 5.54. Also, there is a table including regression models with some more different anthropometric measurements make the  $R^2_{adj}$  value maximize given in the appendices part for the other anthropometric measurements. Then, Table 5.55 shows regression models with stature for each anthropometric measurement.

Table 5.53. Regression equations with the independent variables including age, job-group, body mass and stature for some dimensions.\*

| <b>Anthropometric Variable<br/>(Response)</b> | <b>Regression Model<br/>(y as response)</b>                                                                  | <b>SE</b> | <b>R<sup>2</sup><sub>adj</sub></b> |
|-----------------------------------------------|--------------------------------------------------------------------------------------------------------------|-----------|------------------------------------|
| <b>Acromial (shoulder) height (normal)</b>    | $y = 9.94 - 0.01 * \text{age} + 0.55 * \text{job-group} + 0.04 * \text{body mass} + 0.75 * \text{stature}$   | 3.64      | 73.93 %                            |
| <b>Vertical fingertip reach</b>               | $y = 46.99 - 0.08 * \text{age} + 0.84 * \text{job-group} + 0.01 * \text{body mass} + 0.99 * \text{stature}$  | 7.73      | 54.54 %                            |
| <b>Span</b>                                   | $y = -1.03 + 0.02 * \text{age} + 0.61 * \text{job-group} + 0.03 * \text{body mass} + 0.99 * \text{stature}$  | 3.33      | 84.90 %                            |
| <b>Chest (bust) breadth</b>                   | $y = 14.18 - 0.01 * \text{age} - 0.43 * \text{job-group} + 0.13 * \text{body mass} + 0.04 * \text{stature}$  | 2.18      | 43.41 %                            |
| <b>Shoulder-fingertip length</b>              | $y = -15.20 + 0.05 * \text{age} + 0.07 * \text{job-group} - 0.01 * \text{body mass} + 0.54 * \text{stature}$ | 3.52      | 56.24 %                            |
| <b>Foot length</b>                            | $y = 5.18 - 0.02 * \text{age} + 0.03 * \text{job-group} + 0.01 * \text{body mass} + 0.11 * \text{stature}$   | 1.25      | 31.47 %                            |
| <b>Sitting height (normal)</b>                | $y = 50.45 - 0.02 * \text{age} - 0.96 * \text{job-group} + 0.03 * \text{body mass} + 0.23 * \text{stature}$  | 3.14      | 33.40 %                            |
| <b>Buttock-leg length</b>                     | $y = 26.26 - 0.01 * \text{age} + 0.40 * \text{job-group} + 0.07 * \text{body mass} + 0.43 * \text{stature}$  | 3.72      | 52.64 %                            |
| <b>Head circumference</b>                     | $y = 45.70 - 0.01 * \text{age} - 0.21 * \text{job-group} + 0.04 * \text{body mass} + 0.05 * \text{stature}$  | 1.89      | 17.54 %                            |
| <b>Waist circumference</b>                    | $y = 63.58 + 0.16 * \text{age} + 1.34 * \text{job-group} + 0.62 * \text{body mass} - 0.17 * \text{stature}$  | 7.27      | 52.59 %                            |
| <b>Hand length</b>                            | $y = 3.09 + 0.02 * \text{age} - 0.02 * \text{job-group} + 0.01 * \text{body mass} + 0.01 * \text{stature}$   | 1.00      | 28.57 %                            |

\* All responses (in cm), age (in years), occupation (1 for nonmanual workers and 2 manual workers), body mass (in kg) and stature (in cm)

SE shows standard error of the model;  $R^2_{adj}$  shows percentage of response variable variation.

Table 5.54. Regression equations with the independent variables which provides maximum  $R^2_{adj}$  value for same dimensions in previous table.\*

| <b>Anthropometric Variable (Response)</b>  | <b>Regression Model (y as response)</b>                                                                                                                                                                                                                                                                                                                                               | <b>SE</b> | <b>Mallows' Cp</b> | <b><math>R^2_{adj}</math></b> |
|--------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|--------------------|-------------------------------|
| <b>Acromial (shoulder) height (normal)</b> | $y = 4.60 - 0.06 \cdot \text{chest circumference} - 0.07 \cdot \text{sitting vertical thumb-tip reach} - 0.03 \cdot \text{buttock-popliteal length} + 0.34 \cdot \text{sitting height} + 0.87 \cdot \text{shoulder-elbow length} + 0.98 \cdot \text{elbow height}$                                                                                                                    | 1.65      | 8.2                | 94.62 %                       |
| <b>Vertical fingertip reach</b>            | $y = 5.38 - 0.01 \cdot \text{age} - 0.01 \cdot \text{body mass} - 0.01 \cdot \text{eye height} + 0.01 \cdot \text{waist height} + 0.99 \cdot \text{vertical thumb-tip reach} + 0.13 \cdot \text{shoulder biacromial breadth} + 0.03 \cdot \text{hand length}$                                                                                                                         | 1.93      | 7.9                | 97.14 %                       |
| <b>Span</b>                                | $y = -3.75 + 0.48 \cdot \text{stature} + 0.19 \cdot \text{forward fingertip reach} + 0.45 \cdot \text{elbow span} + 0.04 \cdot \text{hand length}$                                                                                                                                                                                                                                    | 2.79      | 6.4                | 89.41 %                       |
| <b>Chest (bust) breadth</b>                | $y = 12.67 + 0.08 \cdot \text{body mass} + 0.13 \cdot \text{fist height} + 0.18 \cdot \text{standing elbow-to-elbow breadth} - 0.15 \cdot \text{sitting elbow rest height} + 0.21 \cdot \text{shoulder bideltoid breadth}$                                                                                                                                                            | 1.83      | 5.9                | 59.92 %                       |
| <b>Shoulder-fingertip length</b>           | $y = -8.72 + 0.01 \cdot \text{body mass} + 0.58 \cdot \text{stature} + 0.01 \cdot \text{sitting vertical fingertip reach} - 0.63 \cdot \text{fingertip height} + 0.29 \cdot \text{hand length} - 0.01 \cdot \text{age}$                                                                                                                                                               | 2.94      | 7.4                | 69.48 %                       |
| <b>Foot length</b>                         | $y = 4.66 - 0.01 \cdot \text{age} + 0.07 \cdot \text{chest depth} - 0.02 \cdot \text{sitting height} + 0.09 \cdot \text{knee height} + 0.02 \cdot \text{buttock-leg length} + 0.74 \cdot \text{hand length}$                                                                                                                                                                          | 1.05      | 6.6                | 52.29 %                       |
| <b>Sitting height (normal)</b>             | $y = 11.57 + 0.01 \cdot \text{stature} + 0.01 \cdot \text{acromial (shoulder) height} + 0.02 \cdot \text{vertical grip reach} + 0.67 \cdot \text{sitting eye height} + 0.16 \cdot \text{sitting acromial (shoulder) height} + 0.15 \cdot \text{sitting elbow rest height} + 0.26 \cdot \text{knee height} - 0.16 \cdot \text{thigh clearance} - 0.05 \cdot \text{buttock-leg length}$ | 1.51      | 11.7               | 84.57 %                       |
| <b>Buttock-leg length</b>                  | $y = 8.07 - 0.02 \cdot \text{age} + 0.02 \cdot \text{body mass} + 0.19 \cdot \text{stature} + 0.02 \cdot \text{fingertip height} + 0.14 \cdot \text{vertical fingertip reach} - 0.08 \cdot \text{foot length} + 0.38 \cdot \text{buttock-knee length}$                                                                                                                                | 3.29      | 9.8                | 62.95 %                       |

All responses (in cm), age (in years), occupation (1 for nonmanual workers and 2 manual workers), body mass (in kg) and the other measurements (in cm)  
SE shows standard error of the model;  $R^2_{adj}$  shows percentage of response variable variation.

Table 5.54. Regression equations with the independent variables which provides maximum  $R^2_{adj}$  value for same dimensions in previous table (cont'd).

| <b>Anthropometric Variable<br/>(Response)</b> | <b>Regression Model<br/>(y as response)</b>                                                                                                                                                                                                                                                                                                                          | <b>S</b> | <b>Mallows'<br/>Cp</b> | <b><math>R^2_{adj}</math></b> |
|-----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|------------------------|-------------------------------|
| <b>Head circumference</b>                     | $y = 10.19 + 1.15 \times \text{head length} + 1.07 \times \text{head breadth} + 0.16 \times \text{neck circumference} + 0.04 \times \text{waist circumference} + 0.14 \times \text{hip breadth (sitting)} - 0.40 \times \text{hand breadth}$                                                                                                                         | 1.12     | 10.3                   | 71.08 %                       |
| <b>Waist circumference</b>                    | $y = 11.57 + 0.08 \times \text{age} + 0.10 \times \text{body mass} + 0.83 \times \text{chest depth} + 0.20 \times \text{chest breadth} - 0.33 \times \text{head circumference} + 0.87 \times \text{neck circumference} + 0.60 \times \text{chest circumference} + 0.25 \times \text{hip breadth (sitting)}$                                                          | 4.34     | 12.1                   | 82.94 %                       |
| <b>Hand length</b>                            | $y = -1.85 - 0.02 \times \text{job-group} + 0.27 \times \text{foot length} + 0.06 \times \text{foot breadth} + 0.01 \times \text{sitting height} + 0.20 \times \text{bizygomatic (face) breadth} + 0.26 \times \text{hand breadth} + 0.39 \times \text{palm length perpendicular} + 0.73 \times \text{index finger length} + 0.18 \times \text{wrist circumference}$ | 0.56     | 9.9                    | 77.67 %                       |

Table 5.55. Regression equations with stature for some anthropometric measurements.\*

| Anthropometric Variable (Response) | Regression Model<br>(y as response) | SE    | R <sup>2</sup> <sub>adj</sub> |
|------------------------------------|-------------------------------------|-------|-------------------------------|
| Body mass                          | y = -38.15+ 0.67*stature            | 11.63 | 17.18%                        |
| Eye height                         | y = -10.12 + 1.00*stature           | 1.60  | 96.08%                        |
| Shoulder height                    | y = 9.85 + 0.77*stature             | 3.64  | 73.82%                        |
| Elbow height                       | y = 4.25 + 0.60*stature             | 3.85  | 60.33%                        |
| Fingertip height                   | y = 4.70 + 0.35*stature             | 3.49  | 38.14%                        |
| Thumb-tip height                   | y = 16.25+ 0.31*stature             | 3.68  | 30.81%                        |
| Knuckle height                     | y = 19.54 + 0.33*stature            | 4.07  | 29.14%                        |
| Waist height                       | y = 53.91 + 0.29*stature            | 6.66  | 10.12%                        |
| Vertical grip reach                | y = 26.34 + 1.04*stature            | 7.30  | 56.14%                        |
| Vertical thumb-tip reach           | y = 27.77 + 1.06*stature            | 7.49  | 55.88%                        |
| Vertical fingertip reach           | y = 33.38 + 1.06*stature            | 7.75  | 54.32%                        |
| Forward grip reach                 | y = 23.62 + 0.30*stature            | 3.52  | 30.74%                        |
| Forward thumb-tip reach            | y = 23.54 + 0.33*stature            | 4.02  | 29.86%                        |
| Forward fingertip reach            | y = 23.34 + 0.37*stature            | 3.82  | 37.15%                        |
| Span                               | y = 3.77+ 0.99*stature              | 3.35  | 84.68%                        |
| Elbow span                         | y = 7.34 + 0.49*stature             | 3.41  | 56.26%                        |
| Chest (bust) depth                 | y = 14.23 + 0.05*stature            | 2.11  | 2.75%                         |
| Chest (bust) breadth               | y = 6.82 + 0.14*stature             | 2.69  | 14.02%                        |
| Standing elbow-to-elbow breadth    | y = 24.31 + 0.15*stature            | 4.61  | 6.32%                         |
| Shoulder-elbow length              | y = -5.89 + 0.25*stature            | 3.89  | 20.29%                        |
| Shoulder-fingertip length          | y = -6.34 + 0.50*stature            | 3.54  | 55.80%                        |
| Shoulder-grip axis length          | y = -21.17 + 0.52*stature           | 3.87  | 52.96%                        |
| Sitting height                     | y = 43.27 + 0.27*stature            | 3.19  | 31.47%                        |
| Sitting eye height                 | y = 29.12 + 0.29*stature            | 3.19  | 34.84%                        |
| Sitting acromial (shoulder) ht     | y = 27.76 + 0.19*stature            | 3.58  | 15.00%                        |
| Sitting elbow rest height          | y = 31.08 - 0.03*stature            | 2.94  | 0.15%                         |
| Knee height                        | y = -3.74 + 0.32*stature            | 1.99  | 62.40%                        |
| Popliteal height                   | y = 0.40+ 0.24*stature              | 2.57  | 36.28%                        |
| Buttock-knee length                | y = 6.53+ 0.31*stature              | 2.47  | 50.25%                        |
| Buttock-popliteal length           | y = 1.99 + 0.28*stature             | 3.22  | 32.23%                        |
| Thigh clearance                    | y = 3.33 + 0.07*stature             | 1.49  | 12.95%                        |
| Buttock-leg length                 | y = 21.95 + 0.49*stature            | 3.79  | 50.99%                        |
| Sitting vertical grip reach        | y = 31.64+ 0.53*stature             | 5.78  | 34.73%                        |
| Sitting vertical thumb-tip reach   | y = 25.07+ 0.60*stature             | 5.67  | 41.28%                        |
| Sitting vertical fingertip reach   | y = 29.60 + 0.61*stature            | 5.59  | 42.89%                        |
| Sitting forward grip reach         | y = 12.83 + 0.36*stature            | 4.64  | 26.75%                        |
| Sitting forward thumb-tip reach    | y = 11.06 + 0.40*stature            | 4.64  | 31.51%                        |
| Sitting forward fingertip reach    | y = 11.51 + 0.43*stature            | 4.82  | 33.32%                        |
| Head circumference                 | y = 40.31+ 0.10*stature             | 1.95  | 13.09%                        |
| Head length                        | y = 12.54 + 0.04*stature            | 0.95  | 8.18%                         |
| Head breadth                       | y = 13.17 + 0.02*stature            | 0.75  | 2.24%                         |
| Menton-sellion (face) length       | y = 9.94 + 0.01*stature             | 0.80  | 1.51%                         |
| Bizygomatic (face) breadth         | y = 6.95 + 0.04*stature             | 0.89  | 8.94%                         |
| Neck circumference                 | y = 21.42 + 0.10*stature            | 2.87  | 6.59%                         |
| Chest circumference                | y = 52.11+ 0.26*stature             | 7.81  | 6.09%                         |
| Waist circumference                | y = 73.84 + 0.10*stature            | 10.55 | 0.13%                         |
| Hip breadth (sitting)              | y = 20.04+ 0.10*stature             | 2.95  | 6.90%                         |
| Sitting elbow-to elbow breadth     | y = 17.21 + 0.20*stature            | 5.05  | 8.71%                         |
| Shoulder biacromial breadth        | y = 17.92 + 0.12*stature            | 1.96  | 18.76%                        |
| Shoulder bideltoid breadth         | y = 18.54 + 0.16*stature            | 3.12  | 13.87%                        |
| Hand length                        | y = 5.71 + 0.08*stature             | 1.02  | 25.99%                        |

\* All responses (in cm) except body mass (in kg) and stature (in cm)

SE shows standard error of the model; R<sup>2</sup><sub>adj</sub> shows percentage of response variable variation.

Table 5.55. Regression equations with stature for some anthropometric measurements  
(cont'd).

| Anthropometric Variable (Response) | Regression Model<br>(y as response)     | SE   | R <sup>2</sup> <sub>adj</sub> |
|------------------------------------|-----------------------------------------|------|-------------------------------|
| Hand breadth                       | $y = 7.95 + 0.01 \cdot \text{stature}$  | 0.56 | 0.12%                         |
| Palm length perpendicular          | $y = 5.88 + 0.03 \cdot \text{stature}$  | 0.56 | 13.40%                        |
| Index finger length                | $y = 3.49 + 0.02 \cdot \text{stature}$  | 0.50 | 10.55%                        |
| Hand circumference                 | $y = 17.52 + 0.02 \cdot \text{stature}$ | 1.70 | 0.70%                         |
| Wrist circumference                | $y = 7.21 + 0.06 \cdot \text{stature}$  | 1.82 | 6.57%                         |
| Foot length                        | $y = 7.75 + 0.10 \cdot \text{stature}$  | 1.27 | 29.81%                        |
| Foot breadth                       | $y = 9.71 + 0.01 \cdot \text{stature}$  | 0.77 | 0.39%                         |

The followings can be stated from Table 5.53 and Table 5.54.

- Since there is a high correlation between stature and almost all vertical dimensions, regression models including stature as a regressor variable have large  $R^2_{\text{adj}}$  values.
- According to the results of regression models of foot length, there are not so large  $R^2_{\text{adj}}$  values. This means that foot length values can not be accurately predicted with high percentage by using the other anthropometric measurements.
- Regression equations related to hand measurements in Table 5.54 have high percentage of response variable variation since there are high correlations between these dimensions.

## **6. DISCUSSION**

### **6.1. Discussion on the Results of Current Study**

The results of this study are, in general, consistent with a number of other studies in the literature. The discussions on the results are made below.

#### **6.1.1. Age Effect**

Age is found as a significant factor for almost all vertical measurements including horizontal reaching values and also sitting height values including eye and shoulder height while sitting. It affects also the length of extremities. These dimensions are decreasing with aging. This may be attributed to the secular trend and/or shrinking of the spine with increasing age.

#### **6.1.2. Job Effect**

Non manual workers are found significantly taller than manual workers in both stature and sitting height with a difference of about 1.5 cm. One explanation for this result may be that manual workers potentially have some shrinks in their spines due to the wear in their disks under heavy work demands. In addition, nonmanual workers are found significantly heavier than the nonmanual workers. This can be explained by the fact the sedentary work causes slower calorie burn.

#### **6.1.3. BMIP Effect**

BMIP and age are marginally and positively correlated with each other. This is indicating increasing obesity with aging. This can be explained by decrease in metabolic rate inactivity with aging.

#### **6.1.4. Other Effects**

According to the statistical analysis of the results in this study, body mass was found as significantly and positively correlated with drinking habit which means the increase in drinking habit results in increase in body mass. This result may be related to the fact that drinking increases the fat in the body.

Results show that there is decrease in body mass with increase in frequency of sportive activities. This may be because frequent sportive activities make the rate of fat in the body decreases.

### **6.2. Comparison with Previous Studies**

#### **6.2.1. Comparison with Previous Studies of Other Nationalities**

In the literature there is not a single study that considered all 65 measurements that are included in this study. So the comparisons are made with matching dimensions. In addition, age-group, job-group and BMIP-group are also not considered at once in the studies examined.

In Table 6.1, the information of some studies about anthropometric measurements which was compared with the current study was summarized. Also, it is given overall mean and standard deviation values for stature and body mass including those for each age-group. Then, studies show that people at their 30s to 40s have higher body mass values in each of the populations.

There are different age-groups in each study in Table 6.1; and also, measurement values are different for the same age-group for different nations. By this context, it is important to determine age ranges and compare studies in same conditions.

Table 6.1. Stature and body mass values of male of some nationalities.

| Source                               | Country                | Age-groups          | Stature (cm)  | Body Mass (kg) |
|--------------------------------------|------------------------|---------------------|---------------|----------------|
|                                      |                        |                     | $\bar{x}(s)$  | $\bar{x}(s)$   |
| Present Study (2012)                 | Turkey                 | Overall (18-70 yrs) | 171.45 (8.07) | 76.60 (12.78)  |
|                                      |                        | 18-29 yrs           | 176.76 (7.06) | 75.53 (10.76)  |
|                                      |                        | 30-39 yrs           | 174.70 (6.61) | 79.88 (13.35)  |
|                                      |                        | 40-49 yrs           | 171.34 (7.41) | 77.77 (13.21)  |
|                                      |                        | 50-59 yrs           | 168.47 (6.79) | 76.76 (13.16)  |
|                                      |                        | 60-70 yrs           | 165.24 (7.10) | 72.79 (12.80)  |
| Gallwey & Fitzgibbon (1991)          | Ireland                | 17-58 yrs           | 173.08 (5.83) | 73.90 (8.66)   |
| Bolstad <i>et al.</i> (2001)         | Norway                 | Overall (20-39 yrs) | 179.60 (6.60) | 76.20 (10.40)  |
|                                      |                        | 20-29 yrs           | 179.30 (6.40) | 80.10 (11.40)  |
|                                      |                        | 30-39 yrs           | 179.90 (6.80) | 78.20 (11.10)  |
| Mokdad (2002)                        | Algeria                | <25 yrs             | 175.7         | 61             |
|                                      |                        | 25-45 yrs           | 172.4         | 68             |
|                                      |                        | >45 yrs             | 169.7         | 62             |
| Santos <i>et al.</i> (2004)          | USA                    | 60-64 yrs           | 165.80 (7.20) | 78.00 (13.10)  |
|                                      |                        | 65-69 yrs           | 165.30 (7.20) | 73.40 (14.00)  |
|                                      |                        | 70-74 yrs           | 164.70 (6.80) | 72.00 (10.50)  |
|                                      |                        | 75-80 yrs           | 163.50 (6.80) | 71.70 (11.80)  |
|                                      |                        | 80-84 yrs           | 162.50 (7.90) | 69.10 (13.00)  |
|                                      |                        | 85-99 yrs           | 161.60 (5.70) | 64.60 (11.00)  |
| Jinky Leilanie Del Prado-Leon (2007) | Philippines            | Overall             | 167.01 (8.03) | N/A            |
| Dewangan <i>et al.</i> (2008)        | India                  | 18-60 yrs           | 162.00 (6.00) | 56.10 (5.70)   |
| Klamklay <i>et al.</i> (2008)        | Thailand               | 18-25 yrs           | 169.17 (5.60) | 59.65 (8.49)   |
| Coqueiro <i>et al.</i> (2009)        | Brazil                 | 60-64 yrs           | 168.00 (7.00) | 68.78 (12.05)  |
|                                      |                        | 65-69 yrs           | 167.00 (7.00) | 65.02 (12.56)  |
|                                      |                        | 70-74 yrs           | 167.00 (6.00) | 63.04 (11.84)  |
|                                      |                        | 75-80 yrs           | 165.00 (7.00) | 60.74 (14.69)  |
|                                      |                        | >80 yrs             | 163.00 (8.00) | 59.26 (10.48)  |
| Cereda <i>et al.</i> (2010)          | Italy                  | 35-55 yrs           | 174.80 (6.60) | 93.00 (15.00)  |
| Chuan <i>et al.</i> (2010)           | Indonesia<br>Singapore | 18-45 yrs           | 171.50 (5.48) | 63.00 (13.19)  |
|                                      |                        | 18-45 yrs           | 174.00 (5.75) | 68.50 (7.77)   |

As another comparison, Santos *et al.* (2004) conducted a study to measure anthropometric characteristics from a sample of 411 male adults from USA population, ages 60 to 99 through 6 aged-groups. In order to compare with this study, to be accurate the groups of 60-64 and 65-69 years in Santos' study was combined with the group of 60-70 years in which there were equal subjects in these age-groups. In the study of Santos, stature values in erect position for 60-64 and 65-69 years are  $165.80 \pm 7.20$  cm and  $165.30 \pm 7.20$  cm, and body mass values for those are  $78.00 \pm 13.10$  kg and  $73.40 \pm 14.00$  kg. Since stature values for these two groups are independent like body mass values, total mean and variance of 60-69 years can be calculated as following (Pheasant, 2000):

$$\bar{x}_c = \frac{(n_1 * \bar{x}_1) + (n_2 * \bar{x}_2)}{(n_1 + n_2)} \quad (6.1)$$

$$S_c^2 = \frac{S_1^2(n_1-1) + S_2^2(n_2-1)}{(n_1+n_2-1)} + \frac{n_1 * n_2 * (\bar{x}_1 - \bar{x}_2)^2}{(n_1+n_2-1) * (n_1+n_2)} \quad (6.2)$$

where  $n_1$  and  $n_2$  are samples sizes of two samples,  $\bar{x}_1$  and  $\bar{x}_2$  are means of two independent groups,  $S_1^2$  and  $S_2^2$  are sample variances,  $\bar{x}_c$  is combined mean and  $S_c^2$  is combined variance.

Then 165.55 cm is mean of total of these groups and 10.16 cm is standard deviation value of total of these groups for stature through 60-69 years. By this context, it was assumed the homogeneity in the sample sizes of age groups, and then, in that study, a total of 137 men were measured. On the other hand, 75.7 kg is mean of total of these groups and 19.17 kg is standard deviation value of total of these groups for body mass through 60-69 years. To compare the results of these studies and the current study, a t-test was applied. For two sample t-test, t statistic was used which is equal to (Montgomery, 2005):

$$t_0 = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}} \quad (6.3)$$

where  $\bar{x}_1$  and  $\bar{x}_2$  are means,  $S_1^2$  and  $S_2^2$  are sample variances,  $n_1$  and  $n_2$  are sample sizes of two samples.

Table 6.2. Comparison of results of Santos *et al.* (2004) with the current study.

| Study                                       | Stature (cm)    | Body Mass (kg)  |
|---------------------------------------------|-----------------|-----------------|
| Santos <i>et al.</i> (2004) for 60-69 years | 165.55 (10.16)  | 75.7 (19.17)    |
| Present Study for 60-70 years               | 165.24(7.10)    | 72.79(12.80)    |
| Difference                                  | 0.33            | 2.91            |
| T-value                                     | 0.24            | 1.16            |
| P-value                                     | 0.83            | 0.37            |
| Significance                                | Not Significant | Not Significant |

In Table 6.2, the results of t-test to compare the anthropometric measurement values of Santos *et al.* (2004) and the current study can be seen. Results show that there is not significant difference between these populations through such age groups.

Table 6.3. Comparison of results of Rebiffe *et al.* (1983) with the current study.

| Study                                        | Stature (cm)    | Body mass (kg)  |
|----------------------------------------------|-----------------|-----------------|
| Rebiffe <i>et al.</i> (1983) for 30-60 years | 171.5 (6.90)    | 73.00 (11.00)   |
| Present Study for 30-59 years                | 171.44 (7.36)   | 78.11 (13.21)   |
| Difference                                   | 0.06            | -4.89           |
| T-value                                      | 0.03            | -2.18           |
| P-value                                      | 0.98            | 0.16            |
| Significance                                 | Not Significant | Not Significant |

Table 6.3 demonstrates the differences in stature and body mass between Rebiffe *et al.* (1983) and the current study. Rebiffe conducted a study to measure anthropometric characteristics from a sample of French drivers, ages 30 to 60. It can be compared with 30-59 years aged-group in this study in which there is a total of 152 men. In this study, there are 3 aged-groups such as 30-39, 40-49 and 50-59 years; and then, in order to compare this with the study of Rebiffe, these groups can be composed to each others. According to the results of this comparison, there is not a significant difference between French and population of Turkey in terms of both stature and body mass values.

As another study, Table 6.4 indicates Dewangan *et al.* (2008) studied on Indian people through age ranges between 18-60 years and 400 subjects were measured. In order to compare this study with the present study, it was taken into consideration 18-59 years as an aged-group, and there are a total of 205 men in this age range. According to the results, the differences between anthropometric measurements including stature and body mass were significantly different between Indian and Turkish adults since p-value is smaller than level of significance, 0.05. On the other hand, according to the results, representative subjects in population of Turkey are higher and thinner than Indian representatives.

Table 6.4. Comparison of results of Dewangan *et al.* (2008) with the current study.

| Study                                         | Stature (cm)  | Body Mass (kg) |
|-----------------------------------------------|---------------|----------------|
| Dewangan <i>et al.</i> (2008) for 18-60 years | 162 (6)       | 56.1 (5.7)     |
| Present Study for 18-59 years                 | 172.82 (7.63) | 77.44 (12.65)  |
| Difference                                    | -10.82        | -21.34         |
| T-value                                       | -17.69        | -22.99         |
| P-value                                       | <0.001        | <0.001         |
| Significance                                  | Significant   | Significant    |

Table 6.5. Comparison of results of Bolstad *et al.* (2001) with the current study.

| Study                                               | Stature (cm)  | Body Mass (kg)  |
|-----------------------------------------------------|---------------|-----------------|
| <b>Bolstad <i>et al.</i> (2001) for 30-39 years</b> | 179.9 (6.8)   | 80.1 (11.4)     |
| <b>Present Study for 30-39 years</b>                | 174.31 (6.61) | 79.88 (13.35)   |
| <b>Difference</b>                                   | 5.59          | 0.22            |
| <b>T-value</b>                                      | 4.70          | 0.10            |
| <b>P-value</b>                                      | <0.001        | 0.923           |
| <b>Significance</b>                                 | Significant   | Not Significant |

Table 6.5 demonstrates the differences in stature and body mass between Bolstad *et al.* (2001) and current study. Bolstad *et al.* (2001) conducted a study to measure anthropometric characteristics from a sample of 200 male adults from Norwegian population, ages 20 to 39 into two age-groups as 20-29 and 30-39. Thus, 30-39 years aged-group in the present study can be compared with those in the study by Bolstad. According to the results of this comparison, there is a significant difference between Norwegian and population of Turkey in terms of stature; but, the difference in body mass is not significant since p-value is so larger than than level of significance, 0.05. According to the results representative subjects in population of Turkey are smaller than Norwegian representatives in Bolstad *et al.* (2001).

Next, Table 6.6 shows the results of comparison present study with the studies for Irish and Algerian male population. According to the results, there is a significant difference in some measurements including body mass, sitting height, knee height, popliteal height, buttock-popliteal length, hip breadth, and sitting elbow-to-elbow breadth values between Irish and Turkish population while the differences in stature and other vertical measurements are not significant.

According to the results given in Table 6.6, with respect to the comparison between the male population of Algeria and Turkey, there is not significant difference in stature and other vertical dimensions, foot length, knee height and popliteal height. But, for all other dimensions including body mass, chest breadth, sitting height, buttock-knee length, and buttock-popliteal height differ significantly from each other for the males of the populations of Algeria and Turkey. These results may be concluded by the measurement techniques for each anthropometric measurement because in the study by Mokdad there is no information about measurement techniques.

Table 6.6. Comparison of results of present study with the studies for some other nations.

| Anthropometric Measurement | Present Study (2012) for 18-59 yrs | Gallwey & Fitzgibbon (1991) for 17-58 yrs from the survey 1960-62 | p-value (Gallwey & Fitzgibbon vs Present) | Mokdad (2002) for 36 average of years | p-value (Mokdad vs Present) |
|----------------------------|------------------------------------|-------------------------------------------------------------------|-------------------------------------------|---------------------------------------|-----------------------------|
| Body mass (kg)             | 77.44 (12.65)                      | 73.9 (8.66)                                                       | 0.002                                     | 64 (10.90)                            | <0.001                      |
| Stature (e)                | 172.82 (7.63)                      | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Stature (n)                | 172.41 (7.53)                      | 173.0 (5.828)                                                     | 0.397                                     | 172.6 (7.60)                          | 0.760                       |
| Eye height (e)             | 161.98 (7.77)                      | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Eye height (n)             | 161.58 (7.67)                      | N/A                                                               | N/A                                       | 159.7 (6.63)                          | 0.310                       |
| Acr. (shld) ht (e)         | 143.89 (7.41)                      | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Acr. (shld) ht (n)         | 142.18 (6.98)                      | N/A                                                               | N/A                                       | 144.6 (6.71)                          | 0.260                       |
| Elbow height (n)           | 106.91 (5.89)                      | N/A                                                               | N/A                                       | 109.9 (5.28)                          | 0.380                       |
| Fingertip height (n)       | 64.39 (4.33)                       | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Thumb-tip height (n)       | 69.68 (4.46)                       | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Fist(gr.ax, knck)ht (n)    | 76.18 (4.86)                       | N/A                                                               | N/A                                       | 78.6 (4.76)                           | 0.270                       |
| Waist height (n)           | 103.14 (6.82)                      | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Vertical grip rch          | 205.33(10.77)                      | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Vertical th-tip rch        | 210.35(11.04)                      | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Vertical fngtip rch        | 216.3 (11.14)                      | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Forward grip rch           | 74.49 (4.25)                       | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Forward th-tip rch         | 80.43 (4.81)                       | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Forward fngtip rch         | 87.07 (4.78)                       | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Span                       | 174.32 (7.93)                      | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Elbow span                 | 90.99 (5.01)                       | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Chest (bust) depth         | 22.32 (2.07)                       | N/A                                                               | N/A                                       | 21.7 (1.90)                           | 0.084                       |
| Chest (bust) breadth       | 30.59 (2.97)                       | N/A                                                               | N/A                                       | 26.4 (0.61)                           | <0.001                      |
| Stand. e-to-e brt          | 50.98 (4.63)                       | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Shoulder-elbow length      | 36.98 (4.33)                       | N/A                                                               | N/A                                       | 34.9 (3.22)                           | <0.001                      |
| Shoulder-fingertip lgth    | 79.5 (5.35)                        | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Shoulder-fist length       | 67.71 (5.43)                       | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Foot length                | 25.67 (1.49)                       | N/A                                                               | N/A                                       | 25.4 (1.54)                           | 0.870                       |
| Foot breadth               | 9.88 (0.78)                        | N/A                                                               | N/A                                       | 9.5 (0.77)                            | 0.110                       |
| Sitting height(e)          | 90.58 (3.84)                       | 91.13 (3.031)                                                     | 0.250                                     | N/A                                   | N/A                         |
| Sitting height (n)         | 90.17 (3.84)                       | 87.29 (3.250)                                                     | <0.001                                    | 87.0 (3.54)                           | <0.001                      |
| Sitting eye height (e)     | 80.05 (3.92)                       | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Sitting eye height (n)     | 79.65 (3.91)                       | N/A                                                               | N/A                                       | 74.4 (3.91)                           | <0.001                      |
| Sitting shoulder ht (e)    | 62.03 (3.87)                       | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Sitting shoulder ht (n)    | 60.62 (4.01)                       | N/A                                                               | N/A                                       | 60.9 (3.72)                           | 0.792                       |
| Sit. elbow rest ht (n)     | 26.24 (2.98)                       | N/A                                                               | N/A                                       | 19.1 (2.4)                            | <0.001                      |
| Knee height                | 51.76 (3.22)                       | 50.84 (2.765)                                                     | 0.087                                     | 52.2 (3.0)                            | 0.120                       |
| Popliteal height           | 42.62 (3.26)                       | 39.7 (3.401)                                                      | <0.001                                    | 42.2 (3.0)                            | 0.980                       |
| Buttock-knee length        | 60.08 (3.44)                       | 60.01 (2.808)                                                     | 0.830                                     | 57.4 (3.84)                           | <0.001                      |
| Buttock-popliteal lgt      | 50.05 (4)                          | 48.61 (2.352)                                                     | <0.001                                    | 47.5 (2.85)                           | <0.001                      |
| Thigh clearance            | 15.85 (1.56)                       | 15.27 (1.577)                                                     | 0.540                                     | 11.5 (1.53)                           | <0.001                      |
| Buttock-Leg Length         | 105.65 (5.16)                      | N/A                                                               | N/A                                       | 104.1 (4.84)                          | 0.026                       |
| Sit.vertical grip rch      | 123.39 (6.72)                      | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Sit.vertical th-tip rch    | 128.31 (6.9)                       | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Sit.vertical fngtip rch    | 134.63 (6.79)                      | N/A                                                               | N/A                                       | 128.0 (6.4)                           | <0.001                      |
| Sit.forward grip rch       | 73.81 (5.14)                       | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Sit.forward th-tip rch     | 79.38 (5.33)                       | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Sit.forward fngtip rch     | 85.43 (5.66)                       | N/A                                                               | N/A                                       | 88.4 (6.41)                           | <0.001                      |
| Head circumference         | 56.84 (2.08)                       | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Head length                | 18.78 (1.03)                       | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Head breadth               | 15.89 (0.72)                       | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Ment-sellion (face) lgt    | 12.36 (0.82)                       | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Bizygomatic (face) brt     | 13.09 (0.93)                       | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Neck circumference         | 38.25 (3)                          | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Chest circumference        | 96.03 (8.1)                        | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Waist circumference        | 89.78 (10.52)                      | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Hip breadth (sitting)      | 37.84 (3.08)                       | 35.53 (2.533)                                                     | <0.001                                    | 33.7 (2.58)                           | <0.001                      |
| Sit. e-to-e brt (n)        | 51.69 (5.35)                       | 45.43 (5.336)                                                     | <0.001                                    | 43.0 (3.8)                            | <0.001                      |
| Shld biacr. brt            | 38.51 (2.1)                        | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Shld bideltoid brt         | 46.01 (3.34)                       | N/A                                                               | N/A                                       | 40.6 (2.7)                            | <0.001                      |
| Hand length                | 18.83 (1.21)                       | N/A                                                               | N/A                                       | 19.4 (1.4)                            | 0.016                       |
| Hand breadth               | 8.8 (0.57)                         | N/A                                                               | N/A                                       | 8.2 (0.4)                             | <0.001                      |
| Palm lgt perp              | 10.66 (0.62)                       | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Index finger length        | 7.28 (0.53)                        | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Hand Circumference         | 21.32 (1.78)                       | N/A                                                               | N/A                                       | N/A                                   | N/A                         |
| Wrist circumference        | 17.89 (1.93)                       | N/A                                                               | N/A                                       | N/A                                   | N/A                         |

### 6.2.2. Comparison with Previous Studies of Population of Turkey

Table 6.7 shows information of studies about anthropometric measurements of population of Turkey. The empty cells (N/A) in the tables mean that there is no information available. Also, it is given overall mean and standard deviation values for stature and body mass including those for each age-group for population of Turkey. Although there are some other studies in literature about anthropometric characteristics of population of Turkey both male and female genders rather than these ones, not all of them present results of those studies and only some of them publish their conclusions given in the following table in general results for stature and body mass.

Table 6.7. Stature and body mass values of male population of Turkey.

| Source                                                 | Age-groups          | Stature (cm)  | Body Mass (kg) |
|--------------------------------------------------------|---------------------|---------------|----------------|
|                                                        |                     | $\bar{x}(s)$  | $\bar{x}(s)$   |
| <b>Present Study (2012)</b><br>(general population)    | Overall (18-70 yrs) | 171.45 (8.07) | 76.60 (12.78)  |
|                                                        | 18-29 yrs           | 176.76 (7.06) | 75.53 (10.76)  |
|                                                        | 30-39 yrs           | 174.70 (6.61) | 79.88 (13.35)  |
|                                                        | 40-49 yrs           | 171.34 (7.41) | 77.77 (13.21)  |
|                                                        | 50-59 yrs           | 168.47 (6.79) | 76.76 (13.16)  |
|                                                        | 60-70 yrs           | 165.24 (7.10) | 72.79 (12.80)  |
|                                                        |                     |               |                |
| <b>Özok (1981)</b><br>(manual workers)                 | Overall (16-60 yrs) | 168.08 (6.37) | 66.47 (9.32)   |
|                                                        | 16-20 yrs           | 168.93 (6.21) | N/A            |
|                                                        | 21-25 yrs           | 168.65 (6.53) | N/A            |
|                                                        | 26-30 yrs           | 168.12 (6.34) | N/A            |
|                                                        | 31-35 yrs           | 167.96 (6.41) | N/A            |
|                                                        | 36-40 yrs           | 167.10 (6.13) | N/A            |
|                                                        | 41-45 yrs           | 166.92 (5.89) | N/A            |
|                                                        | 46-50 yrs           | 166.21 (5.95) | N/A            |
|                                                        | 51-55 yrs           | 165.81 (6.57) | N/A            |
|                                                        | 56-60 yrs           | 164.03 (5.83) | N/A            |
|                                                        |                     |               |                |
| <b>Kayış and Özok (1991)</b>                           | 18-26 yrs           | 170.20 (6.00) | 63.30 (7.30)   |
| <b>Kayış and Özok (1991)</b><br>(children)             | 6 yrs               | 111.80        | 20.75          |
|                                                        | 7 yrs               | 115.70        | 21.30          |
|                                                        | 8 yrs               | 121.00        | 23.50          |
|                                                        | 9 yrs               | 126.00        | 25.75          |
|                                                        | 10 yrs              | 131.40        | 28.75          |
|                                                        | 11 yrs              | 136.00        | 32.50          |
|                                                        | 12 yrs              | 139.20        | 35.50          |
|                                                        | 13 yrs              | 142.00        | 36.00          |
| <b>Kaya et al (2003)</b><br>(teenagers)                | 15 yrs              | 162.99 (7.51) | 52.49 (8.46)   |
|                                                        | 16 yrs              | 169.38 (6.72) | 57.95 (7.99)   |
|                                                        | 17 yrs              | 171.14 (5.93) | 61.31 (6.95)   |
| <b>Güleç et al. (2006)</b><br>(general population)     | 20-65 yrs           | 168.88 (6.76) | 74.74 (12.32)  |
| <b>İşeri and Arslan (2009)</b><br>(general population) | 18-69 yrs           | 170.80 (8.70) | 77.00 (12.00)  |
| <b>Karadağ et al. (2010)</b>                           | <60 yrs             | 169.19 (6.06) | 85.65 (12.13)  |
|                                                        | >60 yrs             | 165.24 (4.44) | 78.33 (10.06)  |

In Table 6.7 show the results of some studies on stature (cm) and body mass (kg) and those about population of Turkey. There are different age-groups in each study; and also, measurement values are different for the same age-group for different nations. By this context, it is important to determine age ranges and compare studies in same conditions.

In Table 6.8, there are comparison results of Güleç *et al.* (2006) and Özok (1981) with the current study for the all antropometric measurements. In this table, to compare the study by Özok in an accurate way, only manual workers were taken into consideration; but for comparison with the study of Güleç, the values for total adult male subjects in this study were used. T-test was used to demonstrate the difference.

According to Table 6.8, the comparison results of Özok's (1981) and Güleç (2006) with the present study, there are significant differences in almost all anthropometric measurements between these two studies. In general, results showed that there is an increase in vertical measurements which means that in almost thirty years population of Turkey was significantly lengthen. It proves the conclusions of secular trend given in details in previous chapters. Although there are significant differences in some anthropometric measurements, these results may be concluded from the differences in measurement techniques since there is no information about it. For example, in the study by Özok, the subjects would have been measured in the position of bringing arms to the body as much as possible, and in this study the subjects were measured in the position of elbows flexed to the 90 degrees and upper arms did not cling tightly to the body.

The results of the present study indicate that there is an increase in body mass of adult male population of Turkey up to now from 1980s, and it is nearly 8 kg with respect to manual workers. Also, this change is almost 2 kg for the whole population from 2006 to now. This also proves the secular trend. It may be mostly because of the sedentary life-style, dietary, societal changes and change in daily habits resulted from technological development in Turkey. Also, manual worker population of Turkey has been taller as almost 3 cm up to now from 1980s. This change in thirty years may be resulted from change in work styles and then decrease in usage of human work force as much as in previous work styles.

Table 6.8. Comparison of results of the studies about male population of Turkey.

| Anthropometric Measurement | Present Study (2012) for 18-70 yrs | Güleç <i>et al.</i> (2006) for 20-65 yrs | p-value (Güleç vs Present) | Present Study (2012) for manual workers in 18-70 yrs | Özok (1981) for 21-60 yrs | p-value (Özok vs Present) |
|----------------------------|------------------------------------|------------------------------------------|----------------------------|------------------------------------------------------|---------------------------|---------------------------|
| Body mass (kg)             | 76.6 (12.8)                        | 74.74 (12.32)                            | 0.038                      | 74.35 (11.49)                                        | 66.47 (9.32)              | <0.001                    |
| Stature (e)                | 171.5 (8.1)                        | N/A                                      | N/A                        | 170.71 (7.96)                                        | N/A                       | N/A                       |
| Stature (n)                | 171.1(8.0)                         | 168.88 (6.76)                            | <0.001                     | 170.36 (7.83)                                        | 168.08 (6.37)             | 0.002                     |
| Eye height (e)             | 160.7 (8.2)                        | N/A                                      | N/A                        | 160.04 (8.21)                                        | N/A                       | N/A                       |
| Eye height (n)             | 160.3 (8.1)                        | N/A                                      | N/A                        | 159.69 (8.09)                                        | 157.22 (6.23)             | <0.001                    |
| Acr. (shld) ht (e)         | 142.8 (7.5)                        | N/A                                      | N/A                        | 142.30 (7.53)                                        | N/A                       | N/A                       |
| Acr. (shld) ht (n)         | 141.2 (7.1)                        | N/A                                      | N/A                        | 140.87 (7.19)                                        | 138.26 (5.79)             | <0.001                    |
| Elbow height (n)           | 106.2 (6.1)                        | N/A                                      | N/A                        | 105.93 (6.20)                                        | 102.25 (4.74)             | <0.001                    |
| Fingertip height (n)       | 63.8 (4.4)                         | N/A                                      | N/A                        | 63.56 (4.22)                                         | 62.41 (3.46)              | 0.004                     |
| Thumb-tip height (n)       | 69.2 (4.4)                         | N/A                                      | N/A                        | 68.93 (4.16)                                         | N/A                       | N/A                       |
| Fist(gr.ax, knck)ht (n)    | 75.8 (4.8)                         | N/A                                      | N/A                        | 75.62 (4.79)                                         | N/A                       | N/A                       |
| Waist height (n)           | 102.7 (7.0)                        | N/A                                      | N/A                        | 103.74 (7.28)                                        | N/A                       | N/A                       |
| Vertical grip rch          | 203.9(11.0)                        | N/A                                      | N/A                        | 203.61 (10.48)                                       | N/A                       | N/A                       |
| Vertical th-tip rch        | 209.0(11.3)                        | N/A                                      | N/A                        | 208.79 (10.8)                                        | N/A                       | N/A                       |
| Vertical fngtip rch        | 214.9(11.5)                        | N/A                                      | N/A                        | 214.52 (10.88)                                       | 213.2 (8.62)              | 0.190                     |
| Forward grip rch           | 74.1 (4.2)                         | N/A                                      | N/A                        | 73.98 (4.05)                                         | N/A                       | N/A                       |
| Forward th-tip rch         | 80.1 (4.8)                         | N/A                                      | N/A                        | 79.95 (4.77)                                         | N/A                       | N/A                       |
| Forward fngtip rch         | 86.6 (4.8)                         | N/A                                      | N/A                        | 88.18 (4.85)                                         | 90.14 (4.09)              | <0.001                    |
| Span                       | 173.0 (8.6)                        | N/A                                      | N/A                        | 172.58 (8.43)                                        | 171.13 (7.03)             | 0.065                     |
| Elbow span                 | 90.4 (5.2)                         | N/A                                      | N/A                        | 89.62 (4.87)                                         | N/A                       | N/A                       |
| Chest (bust) depth         | 22.4 (2.6)                         | 21.25 (2.30)                             | <0.001                     | 22.22 (2.06)                                         | N/A                       | N/A                       |
| Chest (bust) breadth       | 30.4 (3.5)                         | 29.35 (2.42)                             | <0.001                     | 29.84 (2.42)                                         | N/A                       | N/A                       |
| Stand. e-to-e brt          | 50.8 (4.8)                         | N/A                                      | N/A                        | 50.42 (4.67)                                         | 44.6 (4.11)               | <0.001                    |
| Shoulder-elbow length      | 36.6 (4.4)                         | 35.31 (2.37)                             | <0.001                     | 36.37 (3.98)                                         | N/A                       | N/A                       |
| Shoulder-fingertip lgth    | 79.0 (5.3)                         | 74.8 (3.72)                              | <0.001                     | 78.74 (5.20)                                         | N/A                       | N/A                       |
| Shoulder-fist length       | 67.0 (5.6)                         | N/A                                      | N/A                        | 66.68 (5.33)                                         | N/A                       | N/A                       |
| Foot length                | 25.6 (1.5)                         | 26.15 (1.31)                             | <0.001                     | 25.50 (1.56)                                         | 26.09 (1.26)              | <0.001                    |
| Foot breadth               | 9.9 (0.8)                          | 10.28 (0.68)                             | <0.001                     | 9.94 (0.78)                                          | 10.14 (0.71)              | 0.007                     |
| Sitting height(e)          | 90.2 (3.9)                         | N/A                                      | N/A                        | 89.46 (4.09)                                         | N/A                       | N/A                       |
| Sitting height (n)         | 89.8 (3.9)                         | N/A                                      | N/A                        | 89.1 (4.12)                                          | 88.75 (3.52)              | 0.361                     |
| Sitting eye height (e)     | 79.7 (4.0)                         | N/A                                      | N/A                        | 78.89 (4.3)                                          | N/A                       | N/A                       |
| Sitting eye height (n)     | 79.3 (4.0)                         | N/A                                      | N/A                        | 78.53 (4.31)                                         | 77.56 (3.68)              | 0.016                     |
| Sitting shoulder ht (e)    | 61.7 (3.8)                         | N/A                                      | N/A                        | 61.41 (3.88)                                         | N/A                       | N/A                       |
| Sitting shoulder ht (n)    | 60.4 (3.9)                         | N/A                                      | N/A                        | 60.21 (4.10)                                         | 59.37 (3.06)              | 0.027                     |
| Sit. elbow rest ht (n)     | 26.4 (3.4)                         | N/A                                      | N/A                        | 26.67 (3.14)                                         | N/A                       | N/A                       |
| Knee height                | 51.3 (3.3)                         | 52.3(2.74)-stand                         | <0.001                     | 51.09 (3.40)                                         | 50.3 (2.52)               | 0.012                     |
| Popliteal height           | 42.2 (3.2)                         | 48.39(4.49)-stand                        | <0.001                     | 41.99 (3.23)                                         | 43.17 (2.21)              | <0.001                    |
| Buttock-knee length        | 59.8 (3.5)                         | 55.77(4.02)-stand                        | <0.001                     | 59.40 (3.52)                                         | 61.02 (2.76)              | <0.001                    |
| Buttock-popliteal lgt      | 49.8 (3.9)                         | 47.50(4.17)-stand                        | <0.001                     | 49.60 (3.98)                                         | N/A                       | N/A                       |
| Thigh clearance            | 15.8 (1.9)                         | N/A                                      | N/A                        | 15.72 (1.74)                                         | N/A                       | N/A                       |
| Buttock-Leg Length         | 105.0 (5.4)                        | N/A                                      | N/A                        | 104.74 (5.43)                                        | 106.42 (4.94)             | 0.001                     |
| Sit.vertical grip rch      | 122.5 (7.2)                        | N/A                                      | N/A                        | 121.81 (8.16)                                        | N/A                       | N/A                       |
| Sit.vertical th-tip rch    | 127.4 (7.4)                        | N/A                                      | N/A                        | 126.56 (8.49)                                        | N/A                       | N/A                       |
| Sit.vertical fngtip rch    | 133.7 (7.4)                        | N/A                                      | N/A                        | 132.79 (8.37)                                        | N/A                       | N/A                       |
| Sit.forward grip rch       | 73.4 (5.4)                         | N/A                                      | N/A                        | 72.60 (5.48)                                         | N/A                       | N/A                       |
| Sit.forward th-tip rch     | 78.9 (5.6)                         | N/A                                      | N/A                        | 78.25 (5.72)                                         | N/A                       | N/A                       |
| Sit.forward fngtip rch     | 84.9 (5.9)                         | N/A                                      | N/A                        | 83.85 (6.27)                                         | 91.46 (4.43)              | <0.001                    |
| Head circumference         | 56.7 (4.2)                         | N/A                                      | N/A                        | 56.47 (2.12)                                         | 55.78 (1.78)              | 0.001                     |
| Head length                | 18.8 (1.6)                         | 18.64 (0.79)                             | 0.125                      | 18.77 (0.91)                                         | 18.38 (0.8)               | <0.001                    |
| Head breadth               | 15.8 (1.3)                         | 15.57 (0.78)                             | 0.008                      | 15.74 (0.79)                                         | 16.13 (0.63)              | <0.001                    |
| Ment-sellion (face) lgt    | 12.3 (1.1)                         | N/A                                      | N/A                        | 12.32 (0.84)                                         | 11.74 (0.63)              | <0.001                    |
| Bizygomatic (face) brt     | 13.0 (1.2)                         | N/A                                      | N/A                        | 13.01 (0.88)                                         | N/A                       | N/A                       |
| Neck circumference         | 38.2 (3.8)                         | 37.66 (2.63)                             | 0.034                      | 37.81 (2.71)                                         | N/A                       | N/A                       |
| Chest circumference        | 96.1 (10.1)                        | N/A                                      | N/A                        | 95.14 (7.47)                                         | 91.14 (7.03)              | <0.001                    |
| Waist circumference        | 90.4 (12.0)                        | 89.20 (11.41)                            | 0.152                      | 89.89 (9.99)                                         | 82.81 (10.03)             | <0.001                    |
| Hip breadth (sitting)      | 37.8 (3.9)                         | 31.21(2.55)-stand                        | <0.001                     | 37.63 (2.96)                                         | N/A                       | N/A                       |
| Sit. e-to-e brt (n)        | 51.4 (6.2)                         | N/A                                      | N/A                        | 50.81 (4.89)                                         | N/A                       | N/A                       |
| Shld biacr. brt            | 38.3 (2.2)                         | 39.37 (2.30)                             | <0.001                     | 37.93 (2.18)                                         | 40.55 (2.24)              | <0.001                    |
| Shld bideltoid brt         | 45.8 (3.4)                         | N/A                                      | N/A                        | 45.30 (3.12)                                         | N/A                       | N/A                       |
| Hand length                | 18.8 (1.7)                         | 19.55 (1.05)                             | <0.001                     | 18.71 (1.17)                                         | 19.13 (0.99)              | <0.001                    |
| Hand breadth               | 8.8 (0.8)                          | 8.68 (0.51)                              | 0.024                      | 8.84 (0.53)                                          | 10.49 (0.62)              | <0.001                    |
| Palm lgt perp              | 10.6 (0.9)                         | N/A                                      | N/A                        | 10.65 (0.61)                                         | N/A                       | N/A                       |
| Index finger length        | 7.3 (0.7)                          | 10.67 (0.71)                             | <0.001                     | 7.27 (0.55)                                          | N/A                       | N/A                       |
| Hand Circumference         | 21.4 (2.2)                         | N/A                                      | N/A                        | 21.29 (1.66)                                         | N/A                       | N/A                       |
| Wrist circumference        | 17.8 (2.2)                         | 17.64 (1.03)                             | 0.263                      | 17.66 (1.56)                                         | 17.19 (0.94)              | 0.001                     |

Table 6.9. Comparison with the results in age-groups of Özok's and manual group in present studies in terms of stature (cm).

|                  |              | <b>Present Study(2012)<br/>(manual workers)</b> | <b>Özok (1981)</b> | <b>Difference in Means</b> | <b>CI for Means</b> | <b>p-value</b> | <b>Significance</b> |
|------------------|--------------|-------------------------------------------------|--------------------|----------------------------|---------------------|----------------|---------------------|
| <b>Overall</b>   | $\bar{x}(s)$ | 171.07 (7.97)                                   | 168.08(6.37)       | 2.99                       | 1.92-4.06           | <0.001         | Significant         |
| <b>18-29 yrs</b> | $\bar{x}(s)$ | 178.87 (7.67)                                   | 168.56(11.02)      | 8.31                       | 6.01-10.61          | <0.001         | Significant         |
| <b>30-39 yrs</b> | $\bar{x}(s)$ | 172.23 (6.80)                                   | 167.53(8.87)       | 7.17                       | 3.21-7.39           | <0.001         | Significant         |
| <b>40-49 yrs</b> | $\bar{x}(s)$ | 169.78 (7.85)                                   | 166.57(8.37)       | 4.77                       | 0.94-5.48           | <0.001         | Significant         |
| <b>50-59 yrs</b> | $\bar{x}(s)$ | 168.28 (6.74)                                   | 164.92(8.78)       | 3.55                       | 1.23-5.49           | 0.001          | Significant         |
| <b>60-70 yrs</b> | $\bar{x}(s)$ | 165.55 (6.05)                                   | N/A                | N/A                        | N/A                 | N/A            | N/A                 |

The comparison results in details of age-groups of studies by Özok (1981) and the present one are given in Table 6.9. According to the results given in Table 6.9, there is significant difference between age-groups of manual workers in the study by Özok (1981) and the present one. For overall populations comparison, there is a significant increase in stature by almost 3 cm from 1980s to 2010s.

As another comparison, hand measurements can be thought. By this concept, Ekşioğlu and Silahlı (2012) were interested on grip strength measurements of population of Turkey. Then, there are some common anthropometric dimensions like hand length, hand width and wrist circumference. So, Table 6.10 demonstrates the comparison results between the present study, and Ekşioğlu and Silahlı's study (2012). According to the results, there is no significant difference for hand width and wrist circumference. On the other hand, there is a significant difference in hand length between these two studies, and this may result from the distribution of subjects in these studies with respect to the job-groups. This means that there are a number of manual workers in this study and they have larger hand length values than nonmanual workers.

Table 6.10. Comparison of results of Ekşioğlu and Silahlı (2012) with current study.

|                                                        | <b>Hand Length (cm)</b> | <b>Hand Width (cm)</b> | <b>Wrist Circumference (cm)</b> |
|--------------------------------------------------------|-------------------------|------------------------|---------------------------------|
| <b>Ekşioğlu and Silahlı (2012)<br/>for 18-69 years</b> | 19.10 (0.82)            | 8.75 (0.47)            | 17.65 (0.85)                    |
| <b>Present Study for 18-70 years</b>                   | 18.80 (1.70)            | 8.80 (0.80)            | 17.80 (2.20)                    |
| <b>Difference</b>                                      | 0.30                    | -0.05                  | -0.15                           |
| <b>T-value</b>                                         | 2.16                    | -0.7                   | -0.9                            |
| <b>P-value</b>                                         | 0.032                   | 0.484                  | 0.368                           |
| <b>Significance</b>                                    | Significant             | Not Significant        | Not Significant                 |

## 7. CONCLUSIONS

An up-to-date anthropometric database consisting of 65 body measurements is developed for adult male population of Turkey. Based on the results, summary of the findings drawn from this study in terms of the objectives are as follows:

- (i) An up-to-date anthropometric database including 65 static and dynamic body measurements for adult male population of Turkey is established. To be used by both practitioners and researchers.
- (ii) There is 3 cm increase in stature in comparison to 1980s' male stature indicating a secular trend.
- (iii) Stature and other vertical body dimensions are significantly decreasing with age.
- (iv) Non-manual group is found significantly heavier than manual group.
- (v) There is 8 kg increase in body mass of male manual workers in comparison to 1980s' male body mass.
- (vi) There is a high rate (58%) of obesity among male population of Turkey.
- (vii) Body mass is found as significantly and positively correlated with drinking habit which means the increase in drinking habit results in increase in body mass.
- (viii) Frequency of sportive activities is found as a significant factor (negatively correlated) with body mass. This means that the increase in the frequency of sportive activities results in decrease in body mass.
- (ix) The comparison results with other nationalities indicate that anthropometric data of the male population of Turkey, in general, is similar to the some Southern Europeans and Americans in the USA, greater than Southern Asians and lower than Northern Europeans.

### 7.1. Contributions and Recommendations to Practitioners

The established anthropometry database through this study can serve as a reference for many applications including workspace, job, product, clothing, architectural and vehicle designs for adult male population of Turkey.

The designers in various areas that require human body measurement values can refer to the percentile tables in this manuscript and retrieve the necessary data to design to fit, in general, from 5<sup>th</sup> to 95<sup>th</sup> %tile of adult male population of Turkey. The designs based on the anthropometric data will be comfortable, safe and efficient.

## **7.2. Limitations of the Current Study**

The current study has the following limitations:

- The family roots of the participants included every region of Turkey, but they were living in the metropolitan city of Istanbul and its surrounding areas. Therefore, the effects of living environment of the subjects were assumed negligible.
- The subjects above 70 years old are not considered for this study.

## **APPENDIX A: FORMS**

In the appendix section, the forms that were used in the study are included. These forms are personal consent form, brief medical history form, data collection form and the form of design.

A.1 and A.2: Brief medical history form was prepared for subjects to check if they were healthy enough to participate in the study. This form was also prepared in both languages.

A.3 and A.4: Personal consent form is prepared in both English and Turkish and it includes a detailed description of the aim and procedures of the study. All of the participants voluntarily signed the form in order to participate in the study.

A.5: Data collection form is used for recording the descriptive and anthropometric measurement data of the subjects during the studies.

A.6 and A.7: Instructions were prepared for the subjects in order to inform them about the testing procedure. It was prepared in English and Turkish.

### **A.1. Brief Medical History Form**

Answer the questions, please. Check if answer is “yes”. Give detailed information if it is necessary, please.

- Do you have any defect on your body dimensions such as a burned place?
- Is there any deficiency on your body dimensions such as deficiency in hand, leg, finger...etc.?
- Do you have any difficulty resulted from your anthropometric structure while working?
- Have you ever been undergone an operation resulted in limitation your body motion especially while working?
- How often do you have inspection related to your health?

Please give information about any other problem that affects your abilities while working.

## A.2. Sağlık Anketi

Aşağıdaki soruları lütfen cevaplayınız. Eğer, cevabınız “evet” ise çarpı işaretiyle işaretleyiniz. Gerek duyuluyorsa, cevabınız hakkında lütfen detaylı bilgi veriniz.

- Vücut boyutlarınızda herhangi bir sorun var mı; örneğin yanık bir alan?
- Vücut boyutlarınızda herhangi bir eksiklik var mı; örneğin elinizde, bacağınızda, parmaklarınızda eksiklik olması gibi?
- Vücut anatominizden kaynaklanan sebeplerden dolayı, çalışırken herhangi bir zorluk yaşıyor musunuz?
- Özellikle çalışma esnasında vücut hareketlerinizi kısıtlayan herhangi bir ameliyat geçirdiniz mi?
- Ne kadar sıklıkla sağlık kontrolünden geçiyorsunuz?

Yukarıda belirtilenler dışında, çalışırken yeterliliğinizi etkileyen herhangi bir sorun yaşıyorsanız lütfen belirtiniz.

### A.3. Personal Consent Form

In this study, 64 body measurements including body mass will be determined for the adult male population of Turkey. You are an eligible participant for this study because you do not have any serious health problems that affect your performance especially for reaching postures in this study.

The anthropometric results of this study will be useful for designing workplace and seated places; also hand tools and shoes for male adults in Turkey. The designs that are done by using these results may lead to higher productivity, human centered products and reduced risk of work related disorders.

If you decide to participate in the study, please be aware of the following issues:

- (i) Before the tests, you will be asked questions about birth date, birthplace, the place you live now, family origin city, mother and father's birthplace, your ethnicity, occupation, education status, marital status, frequency of smoking/drinking habit, frequency of sportive activities and controls on your health, genetic disorders.
- (ii) The tests will be done in random order and at the end; there will be 64 body measurements. When you are ready for the study, you will have the appropriate posture without any motion to be measured by the experimenter.
- (iii) Before the tests, participants should not be too hungry, too full or sleepless, and should not consume harmful substances. Moreover, they must be healthy enough to perform the tests.

Your participation is completely voluntary. You may choose to withdraw from participation at any time. All information obtained during this study will be held in strict confidence and only the mean and standard deviation values of the data will be used in the study.

If at any time you have questions regarding this research or if you want to add some contributions to this research, you may contact either Elif EREN or Assoc. Prof. Mahmut EKŞİOĞLU from Department of Industrial Engineering, Boğaziçi University.

By placing your signature below, you will accept that your participation to this study is voluntary. However, you can choose to withdraw from participation at any time at no cost or obligation to you.

Signature of Participant:

Date:

#### A.4. Kişisel Kabul Formu

Bu çalışmada, Türk yetişkin erkek nüfusu için vücut ağırlığını da içerek şekilde 64 adet vücut ölçüsü alınacaktır. Bu çalışmaya engel olacak herhangi bir sağlık probleminizin olmamasından dolayı, çalışmaya uygun durumda bulunmaktasınız.

Çalışmadan elde edilecek antropometrik sonuçlar, iş istasyonları, oturma alanları, el araçları ve ayakkabıların Türkiye insanına göre tasarlanmasında faydalı olacaktır. Bu verileri kullanarak yapılacak tasarımlar hem iş verimini arttırmaya yardımcı olacak hem de iş hastalıklarını azaltmada katkı sağlayacaktır.

Deneye katılmaya karar verdiyseniz lütfen aşağıdaki konulara dikkat ediniz:

- (i) Deney öncesinde size doğum tarihiniz, doğduğunuz ve şu an yaşadığınız yer, aile kökeniniz, anne babanızın doğum yeri, etnik kökeniniz, mesleğiniz, eğitim durumunuz, medeni haliniz, sigara/alkol kullanma sıklığınız, sportif aktivite yapma sıklığınız ve genetik rahatsızlıklarınız sorulacaktır.
- (ii) Rassal sırayla yapılacak olan testlerde 64 vücut ölçüsü alınacaktır. Deney için hazır olduğunuz aman, vücut pozisyonu deney yürütücüsü tarafından size gösterilecektir.
- (iii) Deneylerden önce çok aç, fazla tok veya uykusuz olunmamalı, zararlı maddeler tüketilmemelidir. Ayrıca gerekli olan sağlık şartlarına sahip olmanız gerekmektedir.

Bu deneye katılım tamamen gönüllüdür ve katılım için bir zorlama ile karşılaşmanız söz konusu değildir. İstedığınızde çalışmanın herhangi bir aşamasında çalışmayı terk edebilirsiniz. Elde edilecek kişisel bilgiler kimseyle paylaşılmayacak, tez çalışmasında sadece verilerin ortalaması (kime ait olduğu belirtilmeksizin) ve maksimum ve minimum değerleri belirtilecektir.

Bu çalışmayla ilgili sorularınız ve katkılarınız olması durumunda Boğaziçi Üniversitesi Endüstri Mühendisliği Bölümü'nde Elif EREN veya Doç. Dr. Mahmut EKŞİOĞLU ile temasa geçebilirsiniz

Aşağıya atacağınız imza, bu çalışmaya gönüllü olarak katılmak istediğinizi belirtmektedir. Ayrıca çalışmayı yarıda bırakmanız durumunda, size herhangi bir yükümlülük getirmemektedir.

Katılımcının İmzası:

Tarih:

### A.5. Personel Data Form

Table A.1. General information about the subject.

| Information                          | Datum             |
|--------------------------------------|-------------------|
| Birth date                           | Day: Month: Year: |
| Birthplace                           |                   |
| The place she/he lives now           |                   |
| Family origin city                   |                   |
| Mother and father's birthplace       |                   |
| Ethnicity                            |                   |
| Occupation                           |                   |
| Education Status                     |                   |
| Marital Status                       |                   |
| Frequency of Smoking habit           |                   |
| Frequency of Drinking habit          |                   |
| Frequency of Sportive activities     |                   |
| Dominant Side                        |                   |
| Frequency of controls on your health |                   |

Table A.2. Anthropometric measurements of the subject.

|                                     |  |
|-------------------------------------|--|
| Body mass (kg)                      |  |
| Stature (erect)                     |  |
| Stature (normal)                    |  |
| Eye height (erect)                  |  |
| Eye height (normal)                 |  |
| Acromial (shoulder) height (erect)  |  |
| Acromial (shoulder) height (normal) |  |
| Elbow height (normal)               |  |
| Fingertip height (normal)           |  |
| Thumb-tip height (normal)           |  |
| Fist (grip axis) height (normal)    |  |
| Waist height (normal)               |  |
| Vertical grip reach                 |  |
| Vertical thumb-tip reach            |  |
| Vertical fingertip reach            |  |
| Forward grip reach                  |  |
| Forward thumb-tip reach             |  |
| Forward fingertip reach             |  |
| Span                                |  |
| Elbow span                          |  |
| Chest (bust) depth                  |  |
| Chest (bust) breadth                |  |
| Standing elbow-to-elbow breadth     |  |

Table A.2. Anthropometric measurements of the subject (cont'd).

|                                             |  |
|---------------------------------------------|--|
| Shoulder-elbow length                       |  |
| Shoulder-fingertip length                   |  |
| Shoulder-grip axis length                   |  |
| Foot length                                 |  |
| Foot breadth                                |  |
| Sitting height(erect)                       |  |
| Sitting height (normal)                     |  |
| Sitting eye height (erect)                  |  |
| Sitting eye height (normal)                 |  |
| Sitting acromial (shoulder) height (erect)  |  |
| Sitting acromial (shoulder) height (normal) |  |
| Sitting elbow rest height (normal)          |  |
| Knee height                                 |  |
| Popliteal height                            |  |
| Buttock-knee length                         |  |
| Buttock-popliteal length                    |  |
| Thigh clearance                             |  |
| Buttock-Leg Length                          |  |
| Sitting vertical grip reach                 |  |
| Sitting vertical thumb-tip reach            |  |
| Sitting vertical fingertip reach            |  |
| Sitting forward grip reach                  |  |
| Sitting forward thumb-tip reach             |  |
| Sitting forward fingertip reach             |  |
| Head circumference                          |  |
| Head length                                 |  |
| Head breadth                                |  |
| Menton-sellion (face) length                |  |
| Bizygomatic (face) breadth                  |  |
| Neck circumference                          |  |
| Chest circumference                         |  |
| Waist circumference                         |  |
| Hip breadth (sitting)                       |  |
| Sitting elbow-to elbow breadth (normal)     |  |
| Shoulder biacromial breadth                 |  |
| Shoulder bideltoid breadth                  |  |
| Hand length                                 |  |
| Hand breadth                                |  |
| Palm length perpendicular                   |  |
| Index finger length                         |  |
| Hand Circumference                          |  |
| Wrist circumference                         |  |

### **A.6. Instructions**

- (i) You have read the personal consent form and received information about the study.
- (ii) At the beginning of the study, you should give general information about yourselves which are asked by the experimenter.
- (iii) The experimenter will show you the appropriate posture for each measurement.
- (iv) When you are ready for the studies, inform the experimenter.
- (v) You should have the posture shown by the experimenter without doing any motion through the study.
- (vi) At the end of the study, you will be informed about the value of your body measurements.

### **A.7. Talimatlar**

- (i) Kişisel kabul formunu okudunuz ve deney hakkında bilgi edindiniz.
- (ii) Deneyin başlangıcında, deneyi yaptıran kişi tarafından sizin hakkında genel sorular sorulacaktır.
- (iii) Her ölçüm için uygun pozisyon deneyi yaptıran kişi tarafından size gösterilecektir.
- (iv) Deneye başlamaya hazır olduğunuzda bunu belirtiniz.
- (v) Deneyi yaptıran kişi tarafından size gösterilen vücut duruşunu deney süresince bozmamaya özen gösterin.
- (vi) Deneyin sonunda, vücut ölçüm değerleriniz hakkında bildirileceksiniz.

## APPENDIX B: RESULTS OF STATISTICAL ANALYSIS

### B.1. ANOVA Assumptions

Table B.1. Checking in ANOVA Assumptions.

|                                             | Anderson-Darling Results | Bartlett's Test Results |
|---------------------------------------------|--------------------------|-------------------------|
| Body mass (kg)                              | 0.185                    | 0.483                   |
| Stature (erect)                             | 0.076                    | 0.537                   |
| Stature (normal)                            | 0.072                    | 0.236                   |
| Eye height (erect)                          | 0.071                    | 0.465                   |
| Eye height (normal)                         | 0.069                    | 0.439                   |
| Acromial (shoulder) height (erect)          | 0.308                    | 0.690                   |
| Acromial (shoulder) height (normal)         | 0.125                    | 0.729                   |
| Elbow height (normal)                       | 0.458                    | 0.127                   |
| Fingertip height (normal)                   | 0.213                    | 0.346                   |
| Thumb-tip height (normal)                   | 0.239                    | 0.079                   |
| Fist (grip axis, knuckle) height (normal)   | 0.074                    | 0.181                   |
| Waist height (normal)                       | 0.069                    | 0.103                   |
| Vertical grip reach                         | 0.819                    | 0.060                   |
| Vertical thumb-tip reach                    | 0.863                    | 0.113                   |
| Vertical fingertip reach                    | 0.566                    | 0.067                   |
| Forward grip reach                          | 0.272                    | 0.353                   |
| Forward thumb-tip reach                     | 0.341                    | 0.227                   |
| Forward fingertip reach                     | 0.190                    | 0.668                   |
| Span                                        | 0.143                    | 0.097                   |
| Elbow span                                  | 0.417                    | 0.427                   |
| Chest (bust) depth                          | 0.074                    | 0.568                   |
| Chest (bust) breadth                        | 0.106                    | 0.102                   |
| Standing elbow-to-elbow breadth             | 0.096                    | 0.061                   |
| Shoulder-elbow length                       | 0.076                    | 0.071                   |
| Shoulder-fingertip length                   | 0.071                    | 0.217                   |
| Shoulder-grip axis length                   | 0.073                    | 0.097                   |
| Foot length                                 | 0.083                    | 0.069                   |
| Foot breadth                                | 0.121                    | 0.367                   |
| Sitting height(erect)                       | 0.249                    | 0.253                   |
| Sitting height (normal)                     | 0.496                    | 0.109                   |
| Sitting eye height (erect)                  | 0.505                    | 0.101                   |
| Sitting eye height (normal)                 | 0.513                    | 0.089                   |
| Sitting acromial (shoulder) height (erect)  | 0.072                    | 0.076                   |
| Sitting acromial (shoulder) height (normal) | 0.076                    | 0.067                   |
| Sitting elbow rest height (normal)          | 0.116                    | 0.475                   |
| Knee height                                 | 0.081                    | 0.069                   |
| Popliteal height                            | 0.069                    | 0.075                   |
| Buttock-knee length                         | 0.103                    | 0.089                   |
| Buttock-popliteal length                    | 0.703                    | 0.314                   |
| Thigh clearance                             | 0.062                    | 0.127                   |
| Buttock-leg length                          | 0.074                    | 0.072                   |
| Sitting vertical grip reach                 | 0.081                    | 0.069                   |
| Sitting vertical thumb-tip reach            | 0.082                    | 0.066                   |
| Sitting vertical fingertip reach            | 0.080                    | 0.720                   |
| Sitting forward grip reach                  | 0.079                    | 0.740                   |

Table B.1. Checking in ANOVA Assumptions (cont'd).

|                                                |       |       |
|------------------------------------------------|-------|-------|
| <b>Sitting forward thumb-tip reach</b>         | 0.084 | 0.860 |
| <b>Sitting forward fingertip reach</b>         | 0.082 | 0.135 |
| <b>Head circumference</b>                      | 0.093 | 0.071 |
| <b>Head length</b>                             | 0.069 | 0.088 |
| <b>Head breadth</b>                            | 0.089 | 0.433 |
| <b>Menton-sellion (face) length</b>            | 0.091 | 0.072 |
| <b>Bizygomatic (face) breadth</b>              | 0.063 | 0.077 |
| <b>Neck circumference</b>                      | 0.293 | 0.066 |
| <b>Chest circumference</b>                     | 0.105 | 0.103 |
| <b>Waist circumference</b>                     | 0.163 | 0.207 |
| <b>Hip breadth (sitting)</b>                   | 0.105 | 0.123 |
| <b>Sitting elbow-to elbow breadth (normal)</b> | 0.108 | 0.629 |
| <b>Shoulder biacromial breadth</b>             | 0.155 | 0.477 |
| <b>Shoulder bideltoid breadth</b>              | 0.068 | 0.063 |
| <b>Hand length</b>                             | 0.075 | 0.207 |
| <b>Hand breadth</b>                            | 0.063 | 0.060 |
| <b>Palm length perpendicular</b>               | 0.063 | 0.059 |
| <b>Index finger length</b>                     | 0.078 | 0.304 |
| <b>Hand circumference</b>                      | 0.075 | 0.300 |
| <b>Wrist circumference</b>                     | 0.072 | 0.202 |

## B.2. Post-Hoc Analysis and Regression Models

Table B.2. Tukey's test results for age-group differences in eye height in normal position.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | 1.15                | 1.41           | 0.926    |
| (18-29)-(40-49)      | 4.94                | 1.40           | 0.004    |
| (18-29)-(50-59)      | 7.68                | 1.39           | < 0.001  |
| (18-29)-(60-70)      | 10.68               | 1.45           | < 0.001  |
| (30-39)-(40-49)      | 3.79                | 1.43           | 0.061    |
| (30-39)-(50-59)      | 6.52                | 1.42           | <0.001   |
| (30-39)-(60-70)      | 9.53                | 1.47           | <0.001   |
| (40-49)-(50-59)      | 2.73                | 1.41           | 0.295    |
| (40-49)-(60-70)      | 5.74                | 1.46           | 0.001    |
| (50-59)-(60-70)      | 3.01                | 1.45           | 0.234    |

Table B.3. Tukey's test results for age-group differences in acromial (shoulder) ht (n).

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | -0.62               | 1.28           | 0.988    |
| (18-29)-(40-49)      | 3.16                | 1.27           | 0.092    |
| (18-29)-(50-59)      | 5.65                | 1.26           | 0.001    |
| (18-29)-(60-70)      | 7.42                | 1.31           | <0.001   |
| (30-39)-(40-49)      | 3.79                | 1.29           | 0.028    |
| (30-39)-(50-59)      | 6.27                | 1.29           | <0.001   |
| (30-39)-(60-70)      | 8.05                | 1.34           | <0.001   |
| (40-49)-(50-59)      | 2.48                | 1.28           | 0.293    |
| (40-49)-(60-70)      | 4.26                | 1.32           | 0.011    |
| (50-59)-(60-70)      | 1.78                | 1.31           | 0.660    |

Table B.4. Tukey's test results for age-group differences in elbow height (normal).

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | 1.46                | 1.12           | 0.692    |
| (18-29)-(40-49)      | 3.91                | 1.11           | 0.004    |
| (18-29)-(50-59)      | 5.06                | 1.11           | <0.001   |
| (18-29)-(60-70)      | 6.58                | 1.15           | <0.001   |
| (30-39)-(40-49)      | 2.45                | 1.14           | 0.197    |
| (30-39)-(50-59)      | 3.60                | 1.13           | 0.012    |
| (30-39)-(60-70)      | 5.12                | 1.17           | <0.001   |
| (40-49)-(50-59)      | 1.15                | 1.12           | 0.841    |
| (40-49)-(60-70)      | 2.67                | 1.16           | 0.144    |
| (50-59)-(60-70)      | 1.52                | 1.16           | 0.682    |

Table B.5. Tukey's test results for age-group differences in fingertip height (normal).

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | 0.45                | 0.82           | 0.983    |
| (18-29)-(40-49)      | 2.34                | 0.81           | 0.032    |
| (18-29)-(50-59)      | 2.83                | 0.81           | 0.004    |
| (18-29)-(60-70)      | 4.86                | 0.84           | 0.004    |
| (30-39)-(40-49)      | 1.89                | 0.83           | 0.147    |
| (30-39)-(50-59)      | 2.38                | 0.82           | 0.031    |
| (30-39)-(60-70)      | 4.42                | 0.85           | <0.001   |
| (40-49)-(50-59)      | 0.49                | 0.81           | 0.975    |
| (40-49)-(60-70)      | 2.52                | 0.84           | 0.023    |
| (50-59)-(60-70)      | 2.03                | 0.84           | 0.110    |

Table B.6. Tukey's test results for age-group differences in thumb-tip height (normal).

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | 0.71                | 0.83           | 0.913    |
| (18-29)-(40-49)      | 2.70                | 0.82           | 0.009    |
| (18-29)-(50-59)      | 2.96                | 0.82           | 0.003    |
| (18-29)-(60-70)      | 4.04                | 0.85           | <0.001   |
| (30-39)-(40-49)      | 1.99                | 0.84           | 0.124    |
| (30-39)-(50-59)      | 2.24                | 0.84           | 0.057    |
| (30-39)-(60-70)      | 3.33                | 0.87           | 0.001    |
| (40-49)-(50-59)      | 0.25                | 0.83           | 0.998    |
| (40-49)-(60-70)      | 1.34                | 0.86           | 0.524    |
| (50-59)-(60-70)      | 1.09                | 0.86           | 0.709    |

Table B.7. Tukey's test results for age-group differences in fist (knuckle) ht (normal).

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | 0.61                | 0.92           | 0.964    |
| (18-29)-(40-49)      | 2.55                | 0.91           | 0.040    |
| (18-29)-(50-59)      | 3.34                | 0.90           | 0.002    |
| (18-29)-(60-70)      | 3.87                | 0.94           | <0.001   |
| (30-39)-(40-49)      | 1.94                | 0.93           | 0.221    |
| (30-39)-(50-59)      | 2.73                | 0.92           | 0.025    |
| (30-39)-(60-70)      | 3.27                | 0.95           | 0.006    |
| (40-49)-(50-59)      | 0.79                | 0.91           | 0.908    |
| (40-49)-(60-70)      | 1.33                | 0.95           | 0.627    |
| (50-59)-(60-70)      | 0.53                | 0.94           | 0.978    |

Table B.8. Tukey's test results for age-group differences in waist height (normal).

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | -2.12               | 1.37           | 0.536    |
| (18-29)-(40-49)      | 0.43                | 1.36           | 0.998    |
| (18-29)-(50-59)      | 1.45                | 1.35           | 0.822    |
| (18-29)-(60-70)      | 2.25                | 1.41           | 0.495    |
| (30-39)-(40-49)      | 2.55                | 1.39           | 0.351    |
| (30-39)-(50-59)      | 3.56                | 1.38           | 0.074    |
| (30-39)-(60-70)      | 4.37                | 1.43           | 0.019    |
| (40-49)-(50-59)      | 1.01                | 1.37           | 0.947    |
| (40-49)-(60-70)      | 1.82                | 1.42           | 0.702    |
| (50-59)-(60-70)      | 0.81                | 1.41           | 0.979    |

Table B.9. Tukey's test results for age-group differences in vertical grip reach.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | 2.60                | 1.96           | 0.671    |
| (18-29)-(40-49)      | 7.58                | 1.94           | <0.001   |
| (18-29)-(50-59)      | 11.31               | 1.93           | <0.001   |
| (18-29)-(60-70)      | 13.51               | 2.00           | <0.001   |
| (30-39)-(40-49)      | 4.97                | 1.97           | 0.086    |
| (30-39)-(50-59)      | 8.70                | 1.96           | <0.001   |
| (30-39)-(60-70)      | 10.91               | 2.04           | <0.001   |
| (40-49)-(50-59)      | 3.73                | 1.94           | 0.308    |
| (40-49)-(60-70)      | 5.94                | 2.02           | 0.027    |
| (50-59)-(60-70)      | 2.21                | 2.01           | 0.807    |

Table B.10. Tukey's test results for age-group differences in vertical thumb-tip reach.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | 2.06                | 2.02           | 0.848    |
| (18-29)-(40-49)      | 6.67                | 2.00           | 0.008    |
| (18-29)-(50-59)      | 11.19               | 1.99           | <0.001   |
| (18-29)-(60-70)      | 12.76               | 2.07           | <0.001   |
| (30-39)-(40-49)      | 4.61                | 2.04           | 0.160    |
| (30-39)-(50-59)      | 9.13                | 2.03           | <0.001   |
| (30-39)-(60-70)      | 10.70               | 2.11           | <0.000   |
| (40-49)-(50-59)      | 4.52                | 2.01           | 0.163    |
| (40-49)-(60-70)      | 6.09                | 2.09           | 0.029    |
| (50-59)-(60-70)      | 1.57                | 2.08           | 0.943    |

Table B.11. Tukey's test results for age-group differences in forward grip reach.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | 0.41                | 0.82           | 0.988    |
| (18-29)-(40-49)      | 0.82                | 0.82           | 0.853    |
| (18-29)-(50-59)      | 1.08                | 0.81           | 0.675    |
| (18-29)-(60-70)      | 2.54                | 0.85           | 0.022    |
| (30-39)-(40-49)      | 0.41                | 0.84           | 0.988    |
| (30-39)-(50-59)      | 0.67                | 0.83           | 0.929    |
| (30-39)-(60-70)      | 2.13                | 0.86           | 0.096    |
| (40-49)-(50-59)      | 0.26                | 0.82           | 0.998    |
| (40-49)-(60-70)      | 1.72                | 0.85           | 0.259    |
| (50-59)-(60-70)      | 1.46                | 0.85           | 0.421    |

Table B.12. Tukey's test results for age-group differences in forward fingertip reach.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | 0.565               | 0.93           | 0.974    |
| (18-29)-(40-49)      | 1.14                | 0.92           | 0.732    |
| (18-29)-(50-59)      | 2.26                | 0.92           | 0.099    |
| (18-29)-(60-70)      | 3.55                | 0.95           | 0.002    |
| (30-39)-(40-49)      | 0.57                | 0.94           | 0.974    |
| (30-39)-(50-59)      | 1.69                | 0.94           | 0.366    |
| (30-39)-(60-70)      | 2.99                | 0.97           | 0.018    |
| (40-49)-(50-59)      | 1.12                | 0.93           | 0.743    |
| (40-49)-(60-70)      | 2.43                | 0.96           | 0.088    |
| (50-59)-(60-70)      | 1.29                | 0.96           | 0.660    |

Table B.13. Tukey's test results for age-group differences in span.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | 0.52                | 1.54           | 0.997    |
| (18-29)-(40-49)      | 3.65                | 1.52           | 0.116    |
| (18-29)-(50-59)      | 7.08                | 1.51           | <0.001   |
| (18-29)-(60-70)      | 9.96                | 1.57           | <0.001   |
| (30-39)-(40-49)      | 3.13                | 1.55           | 0.257    |
| (30-39)-(50-59)      | 6.56                | 1.55           | <0.001   |
| (30-39)-(60-70)      | 9.44                | 1.60           | <0.001   |
| (40-49)-(50-59)      | 3.43                | 1.53           | 0.165    |
| (40-49)-(60-70)      | 6.31                | 1.59           | <0.001   |
| (50-59)-(60-70)      | 2.88                | 1.58           | 0.361    |

Table B.14. Tukey's test results for age-group differences in span.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | -0.55               | 0.96           | 0.979    |
| (18-29)-(40-49)      | 0.99                | 0.95           | 0.838    |
| (18-29)-(50-59)      | 2.98                | 0.95           | 0.015    |
| (18-29)-(60-70)      | 4.34                | 0.99           | <0.001   |
| (30-39)-(40-49)      | 1.54                | 0.97           | 0.508    |
| (30-39)-(50-59)      | 3.53                | 0.97           | 0.002    |
| (30-39)-(60-70)      | 4.89                | 1.00           | <0.001   |
| (40-49)-(50-59)      | 1.99                | 0.96           | 0.229    |
| (40-49)-(60-70)      | 3.35                | 0.99           | 0.007    |
| (50-59)-(60-70)      | 1.36                | 0.99           | 0.647    |

Table B.15. Tukey's test results for age-group differences in std.elbow-to-elbow breadth.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | -1.82               | 0.92           | 0.299    |
| (18-29)-(40-49)      | -0.44               | 0.93           | 0.990    |
| (18-29)-(50-59)      | -1.01               | 0.93           | 0.990    |
| (18-29)-(60-70)      | 0.40                | 0.96           | 0.993    |
| (30-39)-(40-49)      | 1.38                | 0.95           | 0.592    |
| (30-39)-(50-59)      | 0.81                | 0.94           | 0.913    |
| (30-39)-(60-70)      | 2.22                | 0.98           | 0.155    |
| (40-49)-(50-59)      | -0.57               | 0.93           | 0.973    |
| (40-49)-(60-70)      | 0.84                | 0.97           | 0.909    |
| (50-59)-(60-70)      | 1.41                | 0.97           | 0.585    |

Table B.16. Tukey's test results for age-group differences in shoulder-elbow length.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | -1.57               | 0.84           | 0.331    |
| (18-29)-(40-49)      | -0.38               | 0.83           | 0.991    |
| (18-29)-(50-59)      | 1.29                | 0.82           | 0.520    |
| (18-29)-(60-70)      | 1.98                | 0.86           | 0.140    |
| (30-39)-(40-49)      | 1.19                | 0.84           | 0.625    |
| (30-39)-(50-59)      | 2.86                | 0.85           | 0.006    |
| (30-39)-(60-70)      | 3.55                | 0.87           | <0.001   |
| (40-49)-(50-59)      | 1.67                | 0.83           | 0.260    |
| (40-49)-(60-70)      | 2.36                | 0.86           | 0.048    |
| (50-59)-(60-70)      | 0.69                | 0.86           | 0.929    |

Table B.17. Tukey's test results for age-group differences in shoulder-grip axis length.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | -0.72               | 1.06           | 0.962    |
| (18-29)-(40-49)      | 0.97                | 1.05           | 0.885    |
| (18-29)-(50-59)      | 3.01                | 1.04           | 0.032    |
| (18-29)-(60-70)      | 4.68                | 1.08           | <0.001   |
| (30-39)-(40-49)      | 1.69                | 1.07           | 0.508    |
| (30-39)-(50-59)      | 3.72                | 1.06           | 0.004    |
| (30-39)-(60-70)      | 5.40                | 1.10           | <0.001   |
| (40-49)-(50-59)      | 2.03                | 1.05           | 0.299    |
| (40-49)-(60-70)      | 3.71                | 1.09           | 0.006    |
| (50-59)-(60-70)      | 1.68                | 1.09           | 0.533    |

Table B.18. Tukey's test results for age-group differences in sitting eye height (normal).

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | 0.94                | 0.74           | 0.711    |
| (18-29)-(40-49)      | 1.31                | 0.74           | 0.389    |
| (18-29)-(50-59)      | 3.19                | 0.73           | <0.001   |
| (18-29)-(60-70)      | 3.39                | 0.76           | <0.001   |
| (30-39)-(40-49)      | 0.36                | 0.75           | 0.989    |
| (30-39)-(50-59)      | 2.25                | 0.75           | 0.021    |
| (30-39)-(60-70)      | 2.44                | 0.77           | 0.014    |
| (40-49)-(50-59)      | 1.89                | 0.74           | 0.080    |
| (40-49)-(60-70)      | 2.08                | 0.77           | 0.052    |
| (50-59)-(60-70)      | 0.20                | 0.76           | 0.999    |

Table B.19. Tukey's test results for age-group differences in sitting acromial (shoulder) ht.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | 0.21                | 0.76           | 0.999    |
| (18-29)-(40-49)      | 1.29                | 0.75           | 0.426    |
| (18-29)-(50-59)      | 1.47                | 0.75           | 0.287    |
| (18-29)-(60-70)      | 2.05                | 0.78           | 0.063    |
| (30-39)-(40-49)      | 1.08                | 0.77           | 0.621    |
| (30-39)-(50-59)      | 1.26                | 0.76           | 0.466    |
| (30-39)-(60-70)      | 1.85                | 0.79           | 0.135    |
| (40-49)-(50-59)      | 0.18                | 0.76           | 0.999    |
| (40-49)-(60-70)      | 0.76                | 0.78           | 0.867    |
| (50-59)-(60-70)      | 0.59                | 0.78           | 0.944    |

Table B.20. Tukey's test results for age-group differences in knee height.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | 0.78                | 0.59           | 0.681    |
| (18-29)-(40-49)      | 2.03                | 0.59           | 0.005    |
| (18-29)-(50-59)      | 2.63                | 0.58           | <0.001   |
| (18-29)-(60-70)      | 3.76                | 0.61           | <0.001   |
| (30-39)-(40-49)      | 1.25                | 0.60           | 0.225    |
| (30-39)-(50-59)      | 1.85                | 0.60           | 0.016    |
| (30-39)-(60-70)      | 2.98                | 0.62           | <0.001   |
| (40-49)-(50-59)      | 0.60                | 0.59           | 0.847    |
| (40-49)-(60-70)      | 1.73                | 0.61           | 0.038    |
| (50-59)-(60-70)      | 1.13                | 0.61           | 0.343    |

Table B.21. Tukey's test results for age-group differences in popliteal height.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | 0.47                | 0.61           | 0.932    |
| (18-29)-(40-49)      | 0.95                | 0.60           | 0.510    |
| (18-29)-(50-59)      | 2.04                | 0.60           | 0.006    |
| (18-29)-(60-70)      | 3.08                | 0.62           | <0.001   |
| (30-39)-(40-49)      | 0.48                | 0.61           | 0.935    |
| (30-39)-(50-59)      | 1.57                | 0.61           | 0.073    |
| (30-39)-(60-70)      | 2.61                | 0.63           | <0.001   |
| (40-49)-(50-59)      | 1.09                | 0.60           | 0.367    |
| (40-49)-(60-70)      | 2.13                | 0.63           | 0.006    |
| (50-59)-(60-70)      | 1.04                | 0.62           | 0.450    |

Table B.22. Tukey's test results for age-group differences in buttock-knee length.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(40-49)      | -1.40               | 0.67           | 0.226    |
| (18-29)-(40-49)      | 0.78                | 0.66           | 0.767    |
| (18-29)-(50-59)      | 0.80                | 0.66           | 0.740    |
| (18-29)-(60-70)      | 1.63                | 0.68           | 0.119    |
| (30-39)-(40-49)      | 2.17                | 0.68           | 0.011    |
| (30-39)-(50-59)      | 2.20                | 0.67           | 0.010    |
| (30-39)-(60-70)      | 3.03                | 0.70           | <0.001   |
| (40-49)-(50-59)      | 0.03                | 0.67           | 1.000    |
| (40-49)-(60-70)      | 0.86                | 0.69           | 0.729    |
| (50-59)-(60-70)      | 0.83                | 0.69           | 0.748    |

Table B.23. Tukey's test results for age-group differences in buttock-popliteal length.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | -2.53               | 0.76           | 0.007    |
| (18-29)-(40-49)      | -0.73               | 0.75           | 0.864    |
| (18-29)-(50-59)      | -0.54               | 0.74           | 0.952    |
| (18-29)-(60-70)      | 0.36                | 0.77           | 0.990    |
| (30-39)-(40-49)      | 1.79                | 0.76           | 0.129    |
| (30-39)-(50-59)      | 1.99                | 0.76           | 0.066    |
| (30-39)-(60-70)      | 2.89                | 0.79           | 0.002    |
| (40-49)-(50-59)      | 0.20                | 0.75           | 0.999    |
| (40-49)-(60-70)      | 1.09                | 0.78           | 0.627    |
| (50-59)-(60-70)      | 0.90                | 0.78           | 0.778    |

Table B.24. Tukey's test results for age-group differences in thigh clearance.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | -0.10               | 0.32           | 0.998    |
| (18-29)-(40-49)      | 0.21                | 0.31           | 0.959    |
| (18-29)-(50-59)      | 0.38                | 0.31           | 0.736    |
| (18-29)-(60-70)      | 0.39                | 0.32           | 0.748    |
| (30-39)-(40-49)      | 0.31                | 0.32           | 0.867    |
| (30-39)-(50-59)      | 0.48                | 0.32           | 0.560    |
| (30-39)-(60-70)      | 0.49                | 0.33           | 0.579    |
| (40-49)-(50-59)      | 0.17                | 0.31           | 0.984    |
| (40-49)-(60-70)      | 0.17                | 0.33           | 0.984    |
| (50-59)-(60-70)      | 0.01                | 0.32           | 1.000    |

Table B.25. Tukey's test results for age-group differences in sitting vertical grip reach.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | 2.32                | 1.29           | 0.373    |
| (18-29)-(40-49)      | 6.12                | 1.27           | <0.001   |
| (18-29)-(50-59)      | 6.61                | 1.27           | <0.001   |
| (18-29)-(60-70)      | 8.66                | 1.32           | <0.001   |
| (30-39)-(40-49)      | 3.81                | 1.30           | 0.028    |
| (30-39)-(50-59)      | 4.30                | 1.29           | 0.008    |
| (30-39)-(60-70)      | 6.34                | 1.34           | <0.001   |
| (40-49)-(50-59)      | 0.49                | 1.28           | 0.995    |
| (40-49)-(60-70)      | 2.53                | 1.33           | 0.313    |
| (50-59)-(60-70)      | 2.04                | 1.32           | 0.534    |

Table B.26. Tukey's test results for age-group differences in sitting vert. thumb-tip reach.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | 2.45                | 1.34           | 0.355    |
| (18-29)-(40-49)      | 5.45                | 1.32           | <0.001   |
| (18-29)-(50-59)      | 7.09                | 1.32           | <0.001   |
| (18-29)-(60-70)      | 8.81                | 1.37           | <0.001   |
| (30-39)-(40-49)      | 3.00                | 1.35           | 0.170    |
| (30-39)-(50-59)      | 4.64                | 1.34           | 0.005    |
| (30-39)-(60-70)      | 6.36                | 1.39           | <0.001   |
| (40-49)-(50-59)      | 1.64                | 1.33           | 0.731    |
| (40-49)-(60-70)      | 3.36                | 1.38           | 0.105    |
| (50-59)-(60-70)      | 1.72                | 1.37           | 0.720    |

Table B.27. Tukey's test results for age-group differences in sitting vertical fingertip reach.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | 2.58                | 1.33           | 0.300    |
| (18-29)-(40-49)      | 5.46                | 1.32           | <0.001   |
| (18-29)-(50-59)      | 7.26                | 1.31           | <0.001   |
| (18-29)-(60-70)      | 8.74                | 1.37           | <0.001   |
| (30-39)-(40-49)      | 2.88                | 1.35           | 0.203    |
| (30-39)-(50-59)      | 4.68                | 1.34           | 0.004    |
| (30-39)-(60-70)      | 6.16                | 1.39           | <0.001   |
| (40-49)-(50-59)      | 1.20                | 1.33           | 0.656    |
| (40-49)-(60-70)      | 3.28                | 1.38           | 0.120    |
| (50-59)-(60-70)      | 1.48                | 1.37           | 0.817    |

Table B.28. Tukey's test results for age-group differences in sitting forward grip reach.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | 0.83                | 1.05           | 0.933    |
| (18-29)-(40-49)      | 1.78                | 1.04           | 0.428    |
| (18-29)-(50-59)      | 2.83                | 1.03           | 0.049    |
| (18-29)-(60-70)      | 3.84                | 1.07           | 0.003    |
| (30-39)-(40-49)      | 0.94                | 1.06           | 0.900    |
| (30-39)-(50-59)      | 2.00                | 1.05           | 0.320    |
| (30-39)-(60-70)      | 3.00                | 1.09           | 0.047    |
| (40-49)-(50-59)      | 1.05                | 1.04           | 0.851    |
| (40-49)-(60-70)      | 2.06                | 1.08           | 0.316    |
| (50-59)-(60-70)      | 1.01                | 1.08           | 0.884    |

B.29. Tukey's test results for age-group differences in sitting forw. thumb-tip reach.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | 0.95                | 1.08           | 0.907    |
| (18-29)-(40-49)      | 2.37                | 1.07           | 0.177    |
| (18-29)-(50-59)      | 2.88                | 1.07           | 0.053    |
| (18-29)-(60-70)      | 4.13                | 1.11           | 0.002    |
| (30-39)-(40-49)      | 1.42                | 1.09           | 0.691    |
| (30-39)-(50-59)      | 1.94                | 1.09           | 0.384    |
| (30-39)-(60-70)      | 3.18                | 1.13           | 0.039    |
| (40-49)-(50-59)      | 0.52                | 1.08           | 0.989    |
| (40-49)-(60-70)      | 1.76                | 1.12           | 0.514    |
| (50-59)-(60-70)      | 1.24                | 1.11           | 0.798    |

Table B.30. Tukey's test results for age-group differences in sitting forward fngrtip reach.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | -0.37               | 1.13           | 0.998    |
| (18-29)-(40-49)      | 2.09                | 1.12           | 0.335    |
| (18-29)-(50-59)      | 3.01                | 1.12           | 0.055    |
| (18-29)-(60-70)      | 3.90                | 1.16           | 0.007    |
| (30-39)-(40-49)      | 2.47                | 1.14           | 0.197    |
| (30-39)-(50-59)      | 3.38                | 1.14           | 0.025    |
| (30-39)-(60-70)      | 4.27                | 1.18           | 0.003    |
| (40-49)-(50-59)      | 0.91                | 1.13           | 0.928    |
| (40-49)-(60-70)      | 1.81                | 1.17           | 0.533    |
| (50-59)-(60-70)      | 0.89                | 1.16           | 0.940    |

Table B.31. Tukey's test results for age-group differences in head length.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | 0.22                | 0.19           | 0.778    |
| (18-29)-(40-49)      | 0.60                | 0.19           | 0.012    |
| (18-29)-(50-59)      | 0.76                | 0.19           | <0.001   |
| (18-29)-(60-70)      | 0.51                | 0.19           | 0.064    |
| (30-39)-(40-49)      | 0.38                | 0.19           | 0.27     |
| (30-39)-(50-59)      | 0.55                | 0.19           | 0.034    |
| (30-39)-(60-70)      | 0.29                | 0.20           | 0.576    |
| (40-49)-(50-59)      | 0.16                | 0.19           | 0.910    |
| (40-49)-(60-70)      | -0.09               | 0.20           | 0.991    |
| (50-59)-(60-70)      | -0.25               | 0.20           | 0.692    |

Table B.32. Tukey's test results for age-group differences in head breadth.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | 0.09                | 0.15           | 0.974    |
| (18-29)-(40-49)      | 0.05                | 0.15           | 0.997    |
| (18-29)-(50-59)      | 0.09                | 0.15           | 0.976    |
| (18-29)-(60-70)      | 0.45                | 0.15           | 0.028    |
| (30-39)-(40-49)      | -0.04               | 0.15           | 0.999    |
| (30-39)-(50-59)      | -0.01               | 0.15           | 1.000    |
| (30-39)-(60-70)      | 0.36                | 0.16           | 0.148    |
| (40-49)-(50-59)      | 0.04                | 0.15           | 0.999    |
| (40-49)-(60-70)      | 0.39                | 0.15           | 0.077    |
| (50-59)-(60-70)      | 0.36                | 0.15           | 0.132    |

Table B.33. Tukey's test results for age-group differences in bizygomatic (face) breadth.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | -0.30               | 0.18           | 0.454    |
| (18-29)-(40-49)      | -0.25               | 0.18           | 0.649    |
| (18-29)-(50-59)      | 0.04                | 0.18           | 1.000    |
| (18-29)-(60-70)      | 0.12                | 0.19           | 0.971    |
| (30-39)-(40-49)      | 0.06                | 0.18           | 0.998    |
| (30-39)-(50-59)      | 0.34                | 0.18           | 0.332    |
| (30-39)-(60-70)      | 0.42                | 0.19           | 0.175    |
| (40-49)-(50-59)      | 0.29                | 0.18           | 0.512    |
| (40-49)-(60-70)      | 0.36                | 0.19           | 0.301    |
| (50-59)-(60-70)      | 0.08                | 0.19           | 0.994    |

Table B.34. Tukey's test results for age-group differences in hip breadth (sitting).

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | 0.73                | 0.60           | 0.750    |
| (18-29)-(40-49)      | 1.27                | 0.60           | 0.209    |
| (18-29)-(50-59)      | 0.88                | 0.60           | 0.574    |
| (18-29)-(60-70)      | 1.13                | 0.62           | 0.356    |
| (30-39)-(40-49)      | 0.55                | 0.61           | 0.899    |
| (30-39)-(50-59)      | 0.16                | 0.61           | 0.999    |
| (30-39)-(60-70)      | 0.40                | 0.63           | 0.968    |
| (40-49)-(50-59)      | -0.39               | 0.60           | 0.967    |
| (40-49)-(60-70)      | -0.14               | 0.62           | 0.999    |
| (50-59)-(60-70)      | 0.25                | 0.62           | 0.995    |

Table B.35. Tukey's test results for age-group differences in sitting e-to e breadth.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | -2.77               | 1.03           | 0.058    |
| (18-29)-(40-49)      | -1.15               | 1.02           | 0.792    |
| (18-29)-(50-59)      | -1.29               | 1.02           | 0.714    |
| (18-29)-(60-70)      | 0.24                | 1.06           | 0.999    |
| (30-39)-(40-49)      | 1.61                | 1.04           | 0.533    |
| (30-39)-(50-59)      | 1.48                | 1.04           | 0.611    |
| (30-39)-(60-70)      | 3.01                | 1.08           | 0.042    |
| (40-49)-(50-59)      | -0.13               | 1.03           | 1.000    |
| (40-49)-(60-70)      | 1.39                | 1.07           | 0.689    |
| (50-59)-(60-70)      | 1.52                | 1.06           | 0.606    |

Table B.36. Tukey's test results for age-group differences in shoulder biacromial breadth.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | -0.46               | 0.41           | 0.790    |
| (18-29)-(40-49)      | 0.74                | 0.41           | 0.358    |
| (18-29)-(50-59)      | 1.15                | 0.40           | 0.036    |
| (18-29)-(60-70)      | 1.55                | 0.42           | 0.002    |
| (30-39)-(40-49)      | 1.20                | 0.41           | 0.029    |
| (30-39)-(50-59)      | 1.61                | 0.41           | <0.001   |
| (30-39)-(60-70)      | 2.01                | 0.43           | <0.001   |
| (40-49)-(50-59)      | 0.41                | 0.41           | 0.856    |
| (40-49)-(60-70)      | 0.81                | 0.42           | 0.312    |
| (50-59)-(60-70)      | 0.40                | 0.42           | 0.876    |

Table B.37. Tukey's test results for age-group differences in shoulder bideltoid breadth.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | -1.43               | 0.65           | 0.171    |
| (18-29)-(40-49)      | 0.65                | 0.64           | 0.849    |
| (18-29)-(50-59)      | 0.68                | 0.64           | 0.822    |
| (18-29)-(60-70)      | 1.36                | 0.66           | 0.238    |
| (30-39)-(40-49)      | 2.09                | 0.65           | 0.012    |
| (30-39)-(50-59)      | 2.12                | 0.65           | 0.009    |
| (30-39)-(60-70)      | 2.80                | 0.67           | <0.001   |
| (40-49)-(50-59)      | 0.03                | 0.64           | 1.000    |
| (40-49)-(60-70)      | 0.71                | 0.67           | 0.824    |
| (50-59)-(60-70)      | 0.68                | 0.66           | 0.845    |

Table B.38. Tukey's test results for age-group differences in hand circumference.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | -1.03               | 0.33           | 0.014    |
| (18-29)-(40-49)      | -0.94               | 0.32           | 0.030    |
| (18-29)-(50-59)      | -1.46               | 0.32           | <0.001   |
| (18-29)-(60-70)      | -1.14               | 0.33           | 0.006    |
| (30-39)-(40-49)      | 0.09                | 0.33           | 0.999    |
| (30-39)-(50-59)      | -0.43               | 0.33           | 0.686    |
| (30-39)-(60-70)      | -0.11               | 0.34           | 0.998    |
| (40-49)-(50-59)      | 0.52                | 0.32           | 0.497    |
| (40-49)-(60-70)      | 0.20                | 0.34           | 0.978    |
| (50-59)-(60-70)      | 0.32                | 0.34           | 0.872    |

Table B.39. Tukey's test results for age-group differences in wrist circumference.

| Age Group Difference | Difference of Means | Standard Error | P -value |
|----------------------|---------------------|----------------|----------|
| (18-29)-(30-39)      | -1.09               | 0.37           | 0.023    |
| (18-29)-(40-49)      | -0.89               | 0.36           | 0.099    |
| (18-29)-(50-59)      | -1.14               | 0.36           | 0.013    |
| (18-29)-(60-70)      | -0.52               | 0.37           | 0.626    |
| (30-39)-(40-49)      | 0.20                | 0.37           | 0.982    |
| (30-39)-(50-59)      | -0.05               | 0.37           | 1.000    |
| (30-39)-(60-70)      | 0.57                | 0.38           | 0.566    |
| (40-49)-(50-59)      | -0.25               | 0.36           | 0.959    |
| (40-49)-(60-70)      | 0.37                | 0.38           | 0.868    |
| (50-59)-(60-70)      | 0.62                | 0.38           | 0.469    |

Table B.40. Tukey's test results for job-group differences in waist height (normal).

| Job Group Difference  | Difference of Means | Standard Error | P -value |
|-----------------------|---------------------|----------------|----------|
| (Non-manual)-(Manual) | -2.05               | 0.88           | 0.020    |

Table B.41. Tukey's test results for job-group differences in elbow span.

| Job Group Difference  | Difference of Means | Standard Error | P -value |
|-----------------------|---------------------|----------------|----------|
| (Non-manual)-(Manual) | 1.53                | 0.65           | 0.018    |

Table B.42. Tukey's test results for job-group differences in foot breadth.

| <b>Job Group Difference</b>  | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Non-manual)-(Manual)</b> | 0.14                       | 0.10                  | 0.14            |

Table B.43. Tukey's test results for job-group differences in sit. eye ht (normal).

| <b>Job Group Difference</b>  | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Non-manual)-(Manual)</b> | 1.53                       | 0.491                 | 0.002           |

Table B.44. Tukey's test results for job-group differences in buttock-knee length.

| <b>Job Group Difference</b>  | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Non-manual)-(Manual)</b> | 0.81                       | 0.44                  | 0.064           |

Table B.45. Tukey's test results for job-group differences in sitting forward grip reach.

| <b>Job Group Difference</b>  | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Non-manual)-(Manual)</b> | 1.55                       | 0.68                  | 0.023           |

Table B.46. Tukey's test results for job-group differences in sitting forw.thumb-tip reach.

| <b>Job Group Difference</b>  | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Non-manual)-(Manual)</b> | 1.35                       | 0.71                  | 0.055           |

Table B.47. Tukey's test results for job-group differences in sitting forward fingertip reach.

| <b>Job Group Difference</b>  | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Non-manual)-(Manual)</b> | 2.21                       | 0.74                  | 0.003           |

Table B.48. Tukey's test results for job-group differences in neck circumference.

| <b>Job Group Difference</b>  | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Non-manual)-(Manual)</b> | 0.86                       | 0.37                  | 0.021           |

Table B.49. Tukey's test results for job-group differences in chest circumference.

| <b>Job Group Difference</b>  | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Non-manual)-(Manual)</b> | 1.89                       | 1.01                  | 0.062           |

Table B.50. Tukey's test results for job-group differences in sitting e-to e breadth.

| <b>Job Group Difference</b>  | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Non-manual)-(Manual)</b> | 1.16                       | 0.67                  | 0.082           |

Table B.51. Tukey's test results for job-group differences in shoulder biacromial breadth.

| <b>Job Group Difference</b>  | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Non-manual)-(Manual)</b> | 0.75                       | 0.27                  | 0.006           |

Table B.52. Tukey's test results for job-group differences in shoulder bideltoid breadth.

| <b>Job Group Difference</b>  | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Non-manual)-(Manual)</b> | 0.95                       | 0.42                  | 0.025           |

Table B.53. Tukey's test results for job-group differences in wrist circumference.

| <b>Job Group Difference</b>  | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Non-manual)-(Manual)</b> | 0.36                       | 0.24                  | 0.124           |

Table B.54. Tukey's test results for BMIP differences in elbow height (normal).

| <b>BMIP Group Difference</b>       | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Normalweight)-(Overweight)</b> | -0.29                      | 0.78                  | 0.714           |

Table B.55. Tukey's test results for BMIP differences in fingertip height (normal).

| <b>BMIP Group Difference</b>       | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Normalweight)-(Overweight)</b> | -0.25                      | 0.58                  | 0.670           |

Table B.56. Tukey's test results for BMIP differences in thumb-tip height (normal).

| <b>BMIP Group Difference</b>       | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Normalweight)-(Overweight)</b> | -0.36                      | 0.59                  | 0.542           |

Table B.57. Tukey's test results for BMIP differences in chest (bust) depth.

| <b>BMIP Group Difference</b>       | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Normalweight)-(Overweight)</b> | -1.97                      | 0.26                  | <0.001          |

Table B.58. Tukey's test results for BMIP differences in standing elbow-to-elbow breadth.

| <b>BMIP Group Difference</b>       | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Normalweight)-(Overweight)</b> | -3.78                      | 0.57                  | <0.001          |

Table B.59. Tukey's test results for BMIP differences in foot breadth.

| <b>BMIP Group Difference</b>       | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Normalweight)-(Overweight)</b> | -0.19                      | 0.10                  | 0.062           |

Table B.60. Tukey's test results for BMIP differences in Sitting acromial (shoulder) height.

| <b>BMIP Group Difference</b>       | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Normalweight)-(Overweight)</b> | -0.85                      | 0.51                  | 0.094           |

Table B.61. Tukey's test results for BMIP differences in sitting elbow rest height (normal).

| <b>BMIP Group Difference</b>       | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Normalweight)-(Overweight)</b> | -1.54                      | 0.37                  | <0.001          |

Table B.62. Tukey's test results for BMIP differences in buttock-knee length.

| BMIP Group Difference       | Difference of Means | Standard Error | P -value |
|-----------------------------|---------------------|----------------|----------|
| (Normalweight)-(Overweight) | -1.24               | 0.45           | 0.006    |

Table B.63. Tukey's test results for BMIP differences in buttock-popliteal length.

| BMIP Group Difference       | Difference of Means | Standard Error | P -value |
|-----------------------------|---------------------|----------------|----------|
| (Normalweight)-(Overweight) | 1.13                | 0.50           | 0.024    |

Table B.64. Tukey's test results for BMIP differences in thigh clearance.

| BMIP Group Difference       | Difference of Means | Standard Error | P -value |
|-----------------------------|---------------------|----------------|----------|
| (Normalweight)-(Overweight) | -1.21               | 0.19           | <0.001   |

Table B.65. Tukey's test results for BMIP differences in sitting vertical fingertip reach.

| BMIP Group Difference       | Difference of Means | Standard Error | P -value |
|-----------------------------|---------------------|----------------|----------|
| (Normalweight)-(Overweight) | -0.12               | 0.97           | 0.904    |

Table B.66. Tukey's test results for BMIP differences in head length.

| BMIP Group Difference       | Difference of Means | Standard Error | P -value |
|-----------------------------|---------------------|----------------|----------|
| (Normalweight)-(Overweight) | -0.13               | 0.12           | 0.285    |

Table B.67. Tukey's test results for BMIP differences in head breadth.

| BMIP Group Difference       | Difference of Means | Standard Error | P -value |
|-----------------------------|---------------------|----------------|----------|
| (Normalweight)-(Overweight) | -0.22               | 0.10           | 0.028    |

Table B.68. Tukey's test results for BMIP differences in bizygomatic (face) breadth.

| BMIP Group Difference       | Difference of Means | Standard Error | P -value |
|-----------------------------|---------------------|----------------|----------|
| (Normalweight)-(Overweight) | -0.26               | 0.11           | 0.020    |

Table B.69. Tukey's test results for BMIP differences inneck circumference.

| BMIP Group Difference       | Difference of Means | Standard Error | P -value |
|-----------------------------|---------------------|----------------|----------|
| (Normalweight)-(Overweight) | -2.83               | 0.34           | <0.001   |

Table B.70. Tukey's test results for BMIP differences in chest circumference.

| BMIP Group Difference       | Difference of Means | Standard Error | P -value |
|-----------------------------|---------------------|----------------|----------|
| (Normalweight)-(Overweight) | -9.05               | 0.88           | <0.001   |

Table B.71. Tukey's test results for BMIP differences in hip breadth (sitting).

| BMIP Group Difference       | Difference of Means | Standard Error | P -value |
|-----------------------------|---------------------|----------------|----------|
| (Normalweight)-(Overweight) | -2.86               | 0.35           | <0.001   |

Table B.72. Tukey's test results for BMIP differences in sitting elbow-to elbow breadth.

| <b>BMIP Group Difference</b>       | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Normalweight)-(Overweight)</b> | -4.01                      | 0.64                  | <0.001          |

Table B.73. Tukey's test results for BMIP differences in shoulder biacromial breadth.

| <b>BMIP Group Difference</b>       | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Normalweight)-(Overweight)</b> | -1.05                      | 0.28                  | <0.001          |

Table B.74. Tukey's test results for BMIP differences in shoulder bideltoid breadth.

| <b>BMIP Group Difference</b>       | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Normalweight)-(Overweight)</b> | -2.28                      | 0.42                  | <0.001          |

Table B.75. Tukey's test results for BMIP differences in hand breadth.

| <b>BMIP Group Difference</b>       | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Normalweight)-(Overweight)</b> | -0.24                      | 0.07                  | <0.001          |

Table B.76. Tukey's test results for BMIP differences in palm length perpendicular.

| <b>BMIP Group Difference</b>       | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Normalweight)-(Overweight)</b> | -0.14                      | 0.08                  | 0.072           |

Table B.77. Tukey's test results for BMIP differences in index finger length.

| <b>BMIP Group Difference</b>       | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Normalweight)-(Overweight)</b> | -0.12                      | 0.07                  | 0.088           |

Table B.78. Tukey's test results for BMIP differences in hand circumference.

| <b>BMIP Group Difference</b>       | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Normalweight)-(Overweight)</b> | -0.87                      | 0.21                  | <0.001          |

Table B.79. Tukey's test results for BMIP differences in wrist circumference.

| <b>BMIP Group Difference</b>       | <b>Difference of Means</b> | <b>Standard Error</b> | <b>P -value</b> |
|------------------------------------|----------------------------|-----------------------|-----------------|
| <b>(Normalweight)-(Overweight)</b> | -1.18                      | 0.23                  | <0.001          |

Table B.80. Regression model table for all other anthropometric measurements.\*

| <b>Anthropometric Variable (Response)</b>        | <b>Regression Model with standard variables (y as response)</b>                                                                                          | <b>Regression Model with maximized <math>R^2_{adj}</math> value (y as response)</b>                                                                                                                                                                                                                                                                                                                                                              |
|--------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Eye height (normal)</b>                       | $y = -12.81 + 0.01*age + 0.23*job\text{-}group - 0.01*body\text{ mass} + 1.01*stature$<br>(S=1.60 ; $R^2_{adj}$ = 96.09% ; Durbin-Watson statistic=1.68) | $y = -12.95 - 0.03*body\text{ mass} + 0.90*stature + 0.09*Thumb\text{-}tip\text{ height} + 0.05*span - 0.28*Sitting\text{ height} + 0.24*Sitting\text{ eye height (normal)} + 0.10*Sitting\text{ elbow rest height} + 0.28*Wrist\text{ circumference} + 0.04*Sitting\text{ forward fingertip reach} - 0.03*Chest\text{ circumference} + 0.06*Shoulder\text{ bideltoid breadth}$<br>(S=1.41 ; $R^2_{adj}$ =96.98% ; Durbin-Watson statistic=1.76) |
| <b>Elbow height (normal)</b>                     | $y = 5.87 - 0.01*age + 0.50*job\text{-}group + 0.05*body\text{ mass} + 0.56*stature$<br>(S=3.83 ; $R^2_{adj}$ =60.73% ; Durbin-Watson statistic=1.44)    | $y = -7.18 + 0.01*age + 0.02*body\text{ mass} + 0.21*stature + 0.01*Eye\text{ height} + 0.28*Acromial\text{ (shoulder) height} + 0.36*Thumb\text{-}tip\text{ height (normal)} + 0.05*Vertical\text{ grip reach} + 0.01*Span - 0.03*Sitting\text{ eye height} + 0.02*Buttock\text{-}leg\text{ length}$<br>(S=3.16 ; $R^2_{adj}$ =73.22% ; Durbin-Watson statistic=1.35)                                                                           |
| <b>Fingertip height (normal)</b>                 | $y = 14.00 - 0.05*age + 0.29*job\text{-}group + 0.04*body\text{ mass} + 0.28*stature$<br>(S=3.46 ; $R^2_{adj}$ =39.47% ; Durbin-Watson statistic=1.48)   | $y = -6.95 - 0.01*age + 0.01*stature + 0.11*stature + 0.71*Thumb\text{-}tip\text{ height} - 0.07*span + 0.06*Vertical\text{ grip reach} + 0.01*Sitting\text{ eye height} + 0.02*Buttock\text{-}leg\text{ length}$<br>(S=1.98 ; $R^2_{adj}$ =80.13% ; Durbin-Watson statistic=1.69)                                                                                                                                                               |
| <b>Thumb-tip height (normal)</b>                 | $y = 25.21 - 0.04*age + 0.05*job\text{-}group + 0.05*body\text{ mass} + 0.25*stature$<br>(S=3.65 ; $R^2_{adj}$ =32.16% ; Durbin-Watson statistic=1.42)   | $y = 8.23 + 0.01*age + 0.01*body\text{ mass} + 0.01*stature + 0.79*Fingertip\text{ height (normal)} + 0.05*Vertical\text{ grip reach} - 0.08*Span + 0.08*Sitting\text{ eye height} + 0.04*Buttock\text{-}leg\text{ length}$<br>(S=2.09 ; $R^2_{adj}$ =77.69% ; Durbin-Watson statistic=1.67)                                                                                                                                                     |
| <b>Fist (grip axis, knuckle) height (normal)</b> | $y = 25.61 - 0.03*age + 0.28*job\text{-}group + 0.02*body\text{ mass} + 0.29*stature$<br>(S=4.08 ; $R^2_{adj}$ =29.03% ; Durbin-Watson statistic=1.38)   | $y = 7.19 + 0.02*age - 0.01*body\text{ mass} - 0.02*stature + 0.82*Fingertip\text{ height} + 0.09*Vertical\text{ grip reach} - 0.0335426*span + 0.0785449*Sitting\text{ eye height} + 0.0205567*Buttock\text{-}leg\text{ length}$<br>(S=2.53 ; $R^2_{adj}$ =72.67% ; Durbin-Watson statistic=1.60)                                                                                                                                               |
| <b>Waist height (normal)</b>                     | $y = 54.34 - 0.04*age + 2.51*job\text{-}group - 0.01*body\text{ mass} + 0.27*stature$<br>(S=6.57 ; $R^2_{adj}$ =12.60% ; Durbin-Watson statistic=0.68)   | $y = 37.04 - 0.03*age + 0.82*Fist\text{ (grip axis, knuckle) height} + 0.01*stature + 0.23*Forward\text{ grip reach} - 0.903*Chest\text{ (bust) breadth} + 0.04*Sitting\text{ acromial (shoulder) height} + 0.03*Buttock\text{-}knee\text{ length} + 0.10*Waist\text{ circumference} - 0.03*Hip\text{ breadth (sitting)} + 0.04*Knee\text{ height}$<br>(S=5.20 ; $R^2_{adj}$ =45.33% ; Durbin-Watson statistic=1.08)                             |

\* All responses (in cm), age (in years), occupation (1 for nonmanual workers and 2 manual workers), body mass (in kg) and the other measurements (in cm)  
 S shows standard error of the model;  $R^2_{adj}$  shows percentage of response variable variation; Durbin Watson statistic shows autocorrelation in the residuals.

Table B.80. Regression model table for all other anthropometric measurements (cont'd).

|                                 |                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                               |
|---------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Vertical grip reach</b>      | $y = 42.00 - 0.10 \cdot \text{age} + 1.20 \cdot \text{job-group} + 0.02 \cdot \text{body mass} + 0.95 \cdot \text{stature}$<br>$(S=7.25 ; R_{\text{adj}}^2=56.79\% ; \text{Durbin-Watson statistic}=0.92)$ | $y = 1.91 - 0.02 \cdot \text{age} + 0.01 \cdot \text{body mass} + 0.02 \cdot \text{Eye height} + 0.0778365 \cdot \text{Waist height} + 0.90 \cdot \text{Vertical thumb-tip reach} + 0.03 \cdot \text{Sitting vertical fingertip reach} + 0.04 \cdot \text{Shoulder biacromial breadth} - 0.12 \cdot \text{Hand circumference}$<br>$(S=1.72 ; R_{\text{adj}}^2=97.56\% ; \text{Durbin-Watson statistic}=1.87)$ |
| <b>Vertical thumb-tip reach</b> | $y = 37.62 - 0.07 \cdot \text{age} + 1.34 \cdot \text{job-group} + 0.01 \cdot \text{body mass} + 1.00 \cdot \text{stature}$<br>$(S=7.47 ; R_{\text{adj}}^2=56.12\% ; \text{Durbin-Watson statistic}=0.86)$ | $y = 0.79 + 0.03 \cdot \text{age} - 0.018 \cdot \text{body mass} + 0.03 \cdot \text{Eye height} - 0.04 \cdot \text{Waist height} + 1.02 \cdot \text{Vertical grip reach} + 0.01 \cdot \text{Sitting vertical fingertip reach} - 0.02 \cdot \text{Shoulder biacromial breadth} - 0.07 \cdot \text{Hand circumference}$<br>$(S=1.83 ; R_{\text{adj}}^2=97.35\% ; \text{Durbin-Watson statistic}=1.82)$          |
| <b>Forward grip reach</b>       | $y = 16.31 + 0.04 \cdot \text{age} + 0.11 \cdot \text{job-group} + 0.01 \cdot \text{body mass} + 0.32 \cdot \text{stature}$<br>$(S=3.51 ; R_{\text{adj}}^2=31.19\% ; \text{Durbin-Watson statistic}=1.36)$ | $y = 3.37 - 0.01 \cdot \text{age} + 0.03 \cdot \text{body mass} - 0.03 \cdot \text{Eye height} + 0.15 \cdot \text{Waist height (normal)} + 0.67 \cdot \text{Forward thumb-tip reach} + 0.08 \cdot \text{Sitting forward grip reach} - 0.27 \cdot \text{Hand breadth}$<br>$(S=1.83 ; R_{\text{adj}}^2=81.21\% ; \text{Durbin-Watson statistic}=1.71)$                                                          |
| <b>Forward thumb-tip reach</b>  | $y = 9.23 + 0.07 \cdot \text{age} + 0.06 \cdot \text{job-group} - 0.02 \cdot \text{body mass} + 0.4 \cdot \text{stature}$<br>$(S=3.96 ; R_{\text{adj}}^2=31.98\% ; \text{Durbin-Watson statistic}=1.38)$   | $y = -3.63 + 0.04 \cdot \text{age} - 0.02 \cdot \text{body mass} + 0.02 \cdot \text{Eye height} + 0.01 \cdot \text{Waist height (normal)} + 0.91 \cdot \text{Forward fingertip reach} + 0.04 \cdot \text{Sitting forward grip reach} - 0.39 \cdot \text{Hand breadth}$<br>$(S=1.73 ; R_{\text{adj}}^2=87.05\% ; \text{Durbin-Watson statistic}=1.82)$                                                         |
| <b>Forward fingertip reach</b>  | $y = 17.09 + 0.04 \cdot \text{age} - 0.39 \cdot \text{job-group} - 0.01 \cdot \text{body mass} + 0.40 \cdot \text{stature}$<br>$(S=3.82 ; R_{\text{adj}}^2=37.31\% ; \text{Durbin-Watson statistic}=1.34)$ | $y = 7.22 - 0.03 \cdot \text{age} + 0.02 \cdot \text{body mass} + 0.038 \cdot \text{Eye height} - 0.01 \cdot \text{Waist height} + 0.86 \cdot \text{Forward thumb-tip reach} + 0.041 \cdot \text{Sitting forward grip reach} + 0.31 \cdot \text{Hand breadth}$<br>$(S=1.68 ; R_{\text{adj}}^2=87.89\% ; \text{Durbin-Watson statistic}=1.75)$                                                                 |
| <b>Elbow span</b>               | $y = 6.73 + 0.02 \cdot \text{age} - 0.7 \cdot \text{job-group} + 0.04 \cdot \text{body mass} + 0.47 \cdot \text{stature}$<br>$(S=3.36 ; R_{\text{adj}}^2=57.44\% ; \text{Durbin-Watson statistic}=2.02)$   | $y = 3.60 + 0.01 \cdot \text{age} - 1.04 \cdot \text{job-group} + 0.06 \cdot \text{stature} - 0.10 \cdot \text{Eye height} + 0.09 \cdot \text{Forward fingertip reach} + 0.48 \cdot \text{span} + 0.09 \cdot \text{shoulder-elbow length}$<br>$(S=2.89 ; R_{\text{adj}}^2=68.50\% ; \text{Durbin-Watson statistic}=2.06)$                                                                                     |
| <b>Chest (bust) depth</b>       | $y = 13.47 + 0.02 \cdot \text{age} + 0.11 \cdot \text{job-group} + 0.10 \cdot \text{body mass} + 0.01 \cdot \text{stature}$<br>$(S=1.74 ; R_{\text{adj}}^2=34.37\% ; \text{Durbin-Watson statistic}=1.88)$ | $y = 3.32 + 0.01 \cdot \text{age} - 0.052 \cdot \text{job-group} + 0.07 \cdot \text{Chest circumference} + 0.04 \cdot \text{Eye height} + 0.11 \cdot \text{Waist circumference} - 0.02 \cdot \text{span}$<br>$(S=1.42 ; R_{\text{adj}}^2=55.98\% ; \text{Durbin-Watson statistic}=1.94)$                                                                                                                      |

Table B.80. Regression model table for all other anthropometric measurements (cont'd).

|                                           |                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                        |
|-------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Standing elbow-to-elbow breadth</b>    | $y = 31.25 + 0.01 \cdot \text{age} + 0.29 \cdot \text{job-group} + 0.21 \cdot \text{body mass} + 0.01 \cdot \text{stature}$<br>$(S=3.91 ; R^2_{\text{adj}}=32.72\% ; \text{Durbin-Watson statistic}=1.60)$  | $y = 5.41 - 0.018 \cdot \text{age} + 0.27 \cdot \text{job-group} + 0.06 \cdot \text{body mass} + 0.51 \cdot \text{Sitting elbow-to-elbow breadth} + 0.32 \cdot \text{Hand circumference} + 0.05 \cdot \text{Acromial (shoulder) height}$<br>$(S=3.07 ; R^2_{\text{adj}}=58.56\% ; \text{Durbin-Watson statistic}=1.73)$                                                                                                |
| <b>Shoulder-elbow length</b>              | $y = -7.07 + 0.01 \cdot \text{age} - 0.14 \cdot \text{job-group} - 0.01 \cdot \text{body mass} + 0.26 \cdot \text{stature}$<br>$(S=3.92 ; R^2_{\text{adj}}=19.42\% ; \text{Durbin-Watson statistic}=1.38)$  | $y = 5.22 - 0.02 \cdot \text{age} + 0.02 \cdot \text{body mass} - 0.55 \cdot \text{Elbow height} - 0.02 \cdot \text{Sitting elbow-to-elbow} + 0.56 \cdot \text{Shoulder-fingertip length} + 0.09 \cdot \text{job-group} + 0.27 \cdot \text{stature}$<br>$(S=2.41 ; R^2_{\text{adj}}=69.41\% ; \text{Durbin-Watson statistic}=1.52)$                                                                                    |
| <b>Shoulder-grip axis length</b>          | $y = -26.82 + 0.03 \cdot \text{age} + 0.08 \cdot \text{job-group} + 0.01 \cdot \text{body mass} + 0.53 \cdot \text{stature}$<br>$(S=3.87 ; R^2_{\text{adj}}=52.96\% ; \text{Durbin-Watson statistic}=1.57)$ | $y = -20.89 + 0.03 \cdot \text{age} - 0.01 \cdot \text{body mass} - 0.43 \cdot \text{Acromial (shoulder) height} + 0.99 \cdot \text{Shoulder-elbow length} - 0.10 \cdot \text{Sitting acromial (shoulder) height} + 0.16 \cdot \text{Shoulder bideltoid breadth} + 0.68 \cdot \text{Elbow height (normal)} + 0.23 \cdot \text{stature}$<br>$(S=3.19 ; R^2_{\text{adj}}=68.06\% ; \text{Durbin-Watson statistic}=1.55)$ |
| <b>Foot breadth</b>                       | $y = 9.91 - 0.01 \cdot \text{age} + 0.18 \cdot \text{job-group} + 0.01 \cdot \text{body mass} - 0.01 \cdot \text{stature}$<br>$(S=0.77 ; R^2_{\text{adj}}=0.72\% ; \text{Durbin-Watson statistic}=1.31)$    | $y = 2.46 - 0.01 \cdot \text{age} + 0.01 \cdot \text{body mass} - 0.02 \cdot \text{stature} + 0.03 \cdot \text{Sitting height} - 0.03 \cdot \text{Popliteal height} + 0.57 \cdot \text{Hand breadth} + 0.04 \cdot \text{Waist height}$<br>$(S=0.59 ; R^2_{\text{adj}}=41.14\% ; \text{Durbin-Watson statistic}=1.66)$                                                                                                  |
| <b>Sitting eye height (normal)</b>        | $y = 34.13 - 0.01 \cdot \text{age} - 1.05 \cdot \text{job-group} + 0.02 \cdot \text{body mass} + 0.27 \cdot \text{stature}$<br>$(S=3.15 ; R^2_{\text{adj}}=36.32\% ; \text{Durbin-Watson statistic}=1.45)$  | $y = -4.45 - 0.01 \cdot \text{age} - 0.16 \cdot \text{job-group} - 0.02 \cdot \text{body mass} + 0.11 \cdot \text{Sitting elbow-to-elbow breadth} - 0.08 \cdot \text{Sitting elbow rest height} + 0.03 \cdot \text{Acromial (shoulder) height} + 0.86 \cdot \text{Sitting height}$<br>$(S=1.88 ; R^2_{\text{adj}}=77.34\% ; \text{Durbin-Watson statistic}=1.16)$                                                      |
| <b>Sitting elbow rest height (normal)</b> | $y = 28.29 + 0.02 \cdot \text{age} + 0.79 \cdot \text{job-group} + 0.09 \cdot \text{body mass} - 0.06 \cdot \text{stature}$<br>$(S=2.74 ; R^2_{\text{adj}}=12.93\% ; \text{Durbin-Watson statistic}=1.54)$  | $y = 30.75 + 0.01 \cdot \text{age} + 0.66 \cdot \text{job-group} + 0.07 \cdot \text{body mass} - 0.19 \cdot \text{Elbow span} - 0.22 \cdot \text{Popliteal height} + 0.43 \cdot \text{Hand length} + 0.13 \cdot \text{Sitting elbow-to-elbow breadth} + 0.01 \cdot \text{Shoulder-elbow length}$<br>$(S=2.45 ; R^2_{\text{adj}}=30.74\% ; \text{Durbin-Watson statistic}=1.55)$                                        |
| <b>Knee height</b>                        | $y = -2.52 - 0.01 \cdot \text{age} + 0.06 \cdot \text{job-group} + 0.02 \cdot \text{body mass} + 0.30 \cdot \text{stature}$<br>$(S=1.98 ; R^2_{\text{adj}}=62.63\% ; \text{Durbin-Watson statistic}=1.49)$  | $y = -11.43 + 0.01 \cdot \text{age} + 0.12 \cdot \text{stature} + 0.07 \cdot \text{Vertical grip reach} + 0.32 \cdot \text{Thigh clearance} + 0.40 \cdot \text{Popliteal height} + 0.08 \cdot \text{Head circumference}$<br>$(S=1.52 ; R^2_{\text{adj}}=78.00\% ; \text{Durbin-Watson statistic}=1.48)$                                                                                                                |

Table B.80. Regression model table for all other anthropometric measurements (cont'd).

|                                         |                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                             |
|-----------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Popliteal height</b>                 | $y = 1.81 - 0.01 \cdot \text{age} - 0.09 \cdot \text{job-group} + 0.01 \cdot \text{body mass} + 0.24 \cdot \text{stature}$<br>$(S=2.59 ; R^2_{\text{adj}}=35.58\% ; \text{Durbin-Watson statistic}=1.46)$  | $y = 5.56 - 0.01 \cdot \text{age} - 0.03 \cdot \text{job-group} + 0.03 \cdot \text{Sitting eye height} + 0.01 \cdot \text{body mass} + 0.77 \cdot \text{Knee height} - 0.37 \cdot \text{Thigh clearance}$<br>$(S=2.13 ; R^2_{\text{adj}}=56.17\% ; \text{Durbin-Watson statistic}=1.43)$                                                                                                                                    |
| <b>Buttock-knee length</b>              | $y = 2.73 + 0.04 \cdot \text{age} - 0.13 \cdot \text{job-group} + 0.08 \cdot \text{body mass} + 0.29 \cdot \text{stature}$<br>$(S=2.23 ; R^2_{\text{adj}}=59.14\% ; \text{Durbin-Watson statistic}=1.59)$  | $y = -0.91 + 0.04 \cdot \text{age} + 0.14 \cdot \text{stature} - 0.01 \cdot \text{Waist height} + 0.09 \cdot \text{Eye height} + 0.14 \cdot \text{Buttock-leg length} + 0.04 \cdot \text{Shoulder bideltoid breadth} - 0.14 \cdot \text{Index finger length} + 0.01 \cdot \text{Menton-sellion (face) length} + 0.06 \cdot \text{body mass}$<br>$(S=2.18 ; R^2_{\text{adj}}=60.93\% ; \text{Durbin-Watson statistic}=1.54)$ |
| <b>Buttock-popliteal length</b>         | $y = -9.26 + 0.07 \cdot \text{age} + 0.03 \cdot \text{job-group} + 0.04 \cdot \text{body mass} + 0.31 \cdot \text{stature}$<br>$(S=3.08 ; R^2_{\text{adj}}=38.05\% ; \text{Durbin-Watson statistic}=1.19)$ | $y = 3.10 + 0.0257283 \cdot \text{age} - 0.16 \cdot \text{stature} - 0.11 \cdot \text{Sitting height} + 0.22 \cdot \text{Eye height} + 0.13 \cdot \text{Knee height} + 0.83 \cdot \text{Buttock-knee length} - 0.23 \cdot \text{Shoulder biacromial breadth}$<br>$(S=2.26 ; R^2_{\text{adj}}=66.62\% ; \text{Durbin-Watson statistic}=1.06)$                                                                                |
| <b>Thigh clearance</b>                  | $y = 5.34 + 0.01 \cdot \text{age} + 0.19 \cdot \text{job-group} + 0.0 \cdot \text{body mass} + 0.03 \cdot \text{stature}$<br>$(S=1.29 ; R^2_{\text{adj}}=34.61\% ; \text{Durbin-Watson statistic}=1.50)$   | $y = 2.16 + 0.01 \cdot \text{age} + 0.24 \cdot \text{job-group} + 0.06 \cdot \text{body mass} - 0.02 \cdot \text{stature} + 0.01 \cdot \text{Thumb-tip height} + 0.03 \cdot \text{Sitting eye height} + 0.10 \cdot \text{Knee height} + 0.09 \cdot \text{Shoulder biacromial breadth}$<br>$(S=1.27 ; R^2_{\text{adj}}=36.88\% ; \text{Durbin-Watson statistic}=1.46)$                                                       |
| <b>Sitting vertical grip reach</b>      | $y = 53.05 - 0.10 \cdot \text{age} - 0.35 \cdot \text{job-group} + 0.05 \cdot \text{body mass} + 0.41 \cdot \text{stature}$<br>$(S=5.69 ; R^2_{\text{adj}}=36.93\% ; \text{Durbin-Watson statistic}=0.98)$ | $y = 10.37 - 0.04 \cdot \text{age} + 0.42 \cdot \text{job-group} - 0.04 \cdot \text{stature} + 0.10 \cdot \text{Sitting eye height} - 0.04 \cdot \text{Buttock-popliteal length} + 0.80 \cdot \text{Sitting vertical fingertip reach} + 0.09 \cdot \text{Sitting forward thumb-tip reach}$<br>$(S=3.17 ; R^2_{\text{adj}}=80.39\% ; \text{Durbin-Watson statistic}=1.48)$                                                   |
| <b>Sitting vertical thumb-tip reach</b> | $y = 44.10 - 0.08 \cdot \text{age} - 0.47 \cdot \text{job-group} + 0.08 \cdot \text{body mass} + 0.48 \cdot \text{stature}$<br>$(S=5.57 ; R^2_{\text{adj}}=43.44\% ; \text{Durbin-Watson statistic}=0.80)$ | $y = -5.84 + 0.01 \cdot \text{age} - 0.02 \cdot \text{job-group} + 0.09 \cdot \text{stature} + 0.11 \cdot \text{Sitting eye height} - 0.12 \cdot \text{Buttock-popliteal length} + 0.76 \cdot \text{Sitting vertical grip reach} + 0.28 \cdot \text{Sitting forward thumb-tip reach}$<br>$(S=2.13 ; R^2_{\text{adj}}=91.73\% ; \text{Durbin-Watson statistic}=1.67)$                                                        |
| <b>Sitting vertical fingertip reach</b> | $y = 49.34 - 0.08 \cdot \text{age} - 0.67 \cdot \text{job-group} + 0.08 \cdot \text{body mass} + 0.48 \cdot \text{stature}$<br>$(S=5.46 ; R^2_{\text{adj}}=45.34\% ; \text{Durbin-Watson statistic}=0.84)$ | $y = -0.03 - 0.01 \cdot \text{age} - 0.20 \cdot \text{job-group} + 0.12 + 0.23 \cdot \text{Sitting eye height} - 0.08 \cdot \text{Buttock-popliteal length} + 0.69 \cdot \text{Sitting vertical grip reach} + 0.19 \cdot \text{Sitting forward thumb-tip reach}$<br>$(S=2.95 ; R^2_{\text{adj}}=84.08\% ; \text{Durbin-Watson statistic}=1.43)$                                                                             |

Table B.80. Regression model table for all other anthropometric measurements (cont'd).

|                                        |                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                             |
|----------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Sitting forward grip reach</b>      | $y = 12.70 + 0.02 \cdot \text{age} - 1.02 \cdot \text{job-group} + 0.01 \cdot \text{body mass} + 0.35 \cdot \text{stature}$<br>$(S=4.63 ; R^2_{\text{adj}}=27.01\% ; \text{Durbin-Watson statistic}=1.14)$ | $y = -3.39 + 0.01 \cdot \text{age} - 0.25 \cdot \text{job-group} - 0.05 \cdot \text{stature} + 0.08 \cdot \text{Sitting eye height} - 0.04 \cdot \text{Buttock-popliteal length} + 0.15 \cdot \text{Sitting vertical grip reach} + 0.79 \cdot \text{Sitting forward thumb-tip reach}$<br>$(S=2.18 ; R^2_{\text{adj}}=83.80\% ; \text{Durbin-Watson statistic}=1.79)$                                        |
| <b>Sitting forward thumb-tip reach</b> | $y = 6.67 + 0.04 \cdot \text{age} - 0.80 \cdot \text{job-group} + 0.01 \cdot \text{body mass} + 0.42 \cdot \text{stature}$<br>$(S=4.63 ; R^2_{\text{adj}}=31.75\% ; \text{Durbin-Watson statistic}=1.02)$  | $y = 1.97 + 0.01 \cdot \text{age} - 0.08 \cdot \text{job-group} + 0.14 \cdot \text{stature} - 0.17 \cdot \text{Sitting eye height} + 0.05 \cdot \text{Buttock-popliteal length} - 0.01 \cdot \text{Sitting vertical grip reach} + 0.873 \cdot \text{Sitting forward grip reach}$<br>$(S=2.30 ; R^2_{\text{adj}}=83.14\% ; \text{Durbin-Watson statistic}=1.67)$                                             |
| <b>Sitting forward fingertip reach</b> | $y = 10.25 + 0.03 \cdot \text{age} - 1.56 \cdot \text{job-group} + 0.02 \cdot \text{body mass} + 0.43 \cdot \text{stature}$<br>$(S=4.76 ; R^2_{\text{adj}}=34.99\% ; \text{Durbin-Watson statistic}=1.11)$ | $y = 7.46 - 0.01 \cdot \text{age} - 0.99 \cdot \text{job-group} + 0.05 \cdot \text{stature} - 0.09 \cdot \text{Forward fingertip reach} + 0.14 \cdot \text{Buttock-popliteal length} + 0.01 \cdot \text{Sitting vertical grip reach} + 0.88 \cdot \text{Sitting forward thumb-tip reach}$<br>$(S=2.43 ; R^2_{\text{adj}}=83.08\% ; \text{Durbin-Watson statistic}=1.67)$                                    |
| <b>Head length</b>                     | $y = 14.43 - 0.01 \cdot \text{age} + 0.10 \cdot \text{job-group} + 0.01 \cdot \text{body mass} + 0.03 \cdot \text{stature}$<br>$(S=0.95 ; R^2_{\text{adj}}=8.71\% ; \text{Durbin-Watson statistic}=1.35)$  | $y = 5.59 - 0.01 \cdot \text{age} + 0.01 \cdot \text{body mass} - 0.01 \cdot \text{stature} + 0.38 \cdot \text{Head circumference} - 0.42 \cdot \text{Head breadth} + 0.16 \cdot \text{Hand length} - 0.18 \cdot \text{Hand circumference}$<br>$(S=0.67 ; R^2_{\text{adj}}=53.84\% ; \text{Durbin-Watson statistic}=1.44)$                                                                                  |
| <b>Head breadth</b>                    | $y = 15.33 - 0.01 \cdot \text{age} - 0.07 \cdot \text{job-group} + 0.01 \cdot \text{body mass} - 0.01 \cdot \text{stature}$<br>$(S=0.73 ; R^2_{\text{adj}}=7.02\% ; \text{Durbin-Watson statistic}=1.72)$  | $y = 7.19 - 0.01 \cdot \text{age} + 0.01 \cdot \text{body mass} - 0.02 \cdot \text{stature} + 0.29 \cdot \text{Head circumference} - 0.31 \cdot \text{Head length} + 0.12 \cdot \text{Hand length} - 0.06 \cdot \text{Hand circumference}$<br>$(S=0.58 ; R^2_{\text{adj}}=42.21\% ; \text{Durbin-Watson statistic}=1.61)$                                                                                   |
| <b>Menton-sellion (face) length</b>    | $y = 9.69 + 0.01 \cdot \text{age} + 0.01 \cdot \text{job-group} + 0.01 \cdot \text{body mass} + 0.01 \cdot \text{stature}$<br>$(S=0.80 ; R^2_{\text{adj}}=2.57\% ; \text{Durbin-Watson statistic}=1.31)$   | $y = 3.89 + 0.01 \cdot \text{age} - 0.01 \cdot \text{body mass} - 0.01 \cdot \text{Eye height} + 0.057 \cdot \text{Sitting eye height} - 0.02 \cdot \text{Bizygomatic (face) breadth} - 0.01 \cdot \text{Sitting elbow-to elbow breadth} + 0.09 \cdot \text{Shoulder bideltoid breadth} + 0.03 \cdot \text{Sitting height}$<br>$(S=0.74 ; R^2_{\text{adj}}=17.13\% ; \text{Durbin-Watson statistic}=1.41)$  |
| <b>Bizygomatic (face) breadth</b>      | $y = 6.60 + 0.01 \cdot \text{age} + 0.05 \cdot \text{job-group} + 0.01 \cdot \text{body mass} + 0.03 \cdot \text{stature}$<br>$(S=0.88 ; R^2_{\text{adj}}=11.20\% ; \text{Durbin-Watson statistic}=1.12)$  | $y = 7.96 + 0.01 \cdot \text{age} + 0.01 \cdot \text{body mass} + 0.03 \cdot \text{Eye height} + 0.08 \cdot \text{Sitting eye height} - 0.03 \cdot \text{Menton-sellion (face) length} + 0.01 \cdot \text{Sitting elbow-to elbow breadth} + 0.06 \cdot \text{Shoulder bideltoid breadth} - 0.10 \cdot \text{Sitting height}$<br>$(S=0.84 ; R^2_{\text{adj}}=18.63\% ; \text{Durbin-Watson statistic}=1.24)$ |

Table B.80. Regression model table for all other anthropometric measurements (cont'd).

|                                                |                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                        |
|------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Neck circumference</b>                      | $y = 21.13 + 0.03 \cdot \text{age} - 0.27 \cdot \text{job-group} + 0.14 \cdot \text{body mass} + 0.03 \cdot \text{stature}$<br>(S=2.30 ; $R^2_{\text{adj}}$ =39.79% ; Durbin-Watson statistic=1.48) | $y = 5.25 + 0.03 \cdot \text{age} - 0.28 \cdot \text{job-group} + 0.11 \cdot \text{body mass} + 0.03 \cdot \text{Eye height} - 0.06 \cdot \text{Acromial (shoulder) height} + 0.92 \cdot \text{Bizygomatic (face) breadth} + 0.51 \cdot \text{Menton-sellion (face) length} + 0.15 \cdot \text{Sitting acromial (shoulder) height}$<br>(S=2.07 ; $R^2_{\text{adj}}$ =51.51% ; Durbin-Watson statistic=1.61)            |
| <b>Chest circumference</b>                     | $y = 55.31 + 0.07 \cdot \text{age} - 0.05 \cdot \text{job-group} + 0.43 \cdot \text{body mass} + 0.03 \cdot \text{stature}$<br>(S=5.80 ; $R^2_{\text{adj}}$ =48.18% ; Durbin-Watson statistic=1.26) | $y = 29.64 - 0.03 \cdot \text{age} - 0.80 \cdot \text{job-group} + 0.08 \cdot \text{body mass} + 0.10 \cdot \text{Eye height} + 0.25 \cdot \text{Elbow height} - 0.21 \cdot \text{Acromial (shoulder) height} + 0.51 \cdot \text{Chest (bust) depth} - 0.41 \cdot \text{Head length} + 0.50 \cdot \text{Waist circumference}$<br>(S=3.83 ; $R^2_{\text{adj}}$ =77.30% ; Durbin-Watson statistic=1.36)                  |
| <b>Hip breadth (sitting)</b>                   | $y = 28.64 - 0.02 \cdot \text{age} + 0.49 \cdot \text{job-group} + 0.15 \cdot \text{body mass} - 0.01 \cdot \text{stature}$<br>(S=2.42 ; $R^2_{\text{adj}}$ =37.15% ; Durbin-Watson statistic=1.48) | $y = 21.40 - 0.04 \cdot \text{age} + 0.08 \cdot \text{body mass} - 0.03 \cdot \text{Eye height} + 0.02 \cdot \text{Waist height} + 0.09 \cdot \text{Waist circumference} + 0.06 \cdot \text{Sitting elbow-to elbow breadth} + 0.04 \cdot \text{Sitting forward grip reach}$<br>(S=2.31 ; $R^2_{\text{adj}}$ =42.97 ; Durbin-Watson statistic=1.50)                                                                     |
| <b>Sitting elbow-to elbow breadth (normal)</b> | $y = 23.40 + 0.02 \cdot \text{age} - 0.04 \cdot \text{job-group} + 0.24 \cdot \text{body mass} + 0.05 \cdot \text{stature}$<br>(S=4.24 ; $R^2_{\text{adj}}$ =35.48% ; Durbin-Watson statistic=1.33) | $y = 2.58 - 0.077 \cdot \text{age} - 0.33 \cdot \text{job-group} + 0.06 \cdot \text{body mass} + 0.14 \cdot \text{Waist circumference} + 1.23 \cdot \text{Hand circumference} - 0.03 \cdot \text{Acromial (shoulder) height} + 0.32 \cdot \text{Hip breadth (sitting)}$<br>(S=3.68 ; $R^2_{\text{adj}}$ =51.38% ; Durbin-Watson statistic=1.41)                                                                        |
| <b>Shoulder biacromial breadth</b>             | $y = 26.00 - 0.02 \cdot \text{age} - 0.29 \cdot \text{job-group} + 0.07 \cdot \text{body mass} + 0.05 \cdot \text{stature}$<br>(S=1.76 ; $R^2_{\text{adj}}$ =34.54% ; Durbin-Watson statistic=1.79) | $y = 8.77 - 0.01 \cdot \text{age} - 0.17 \cdot \text{job-group} + 0.10 \cdot \text{stature} - 0.06 \cdot \text{Eye height} + 0.03 \cdot \text{Sitting height} - 0.10 \cdot \text{Buttock-popliteal length} + 0.05 \cdot \text{Sitting forward thumb-tip reach} + 0.45 \cdot \text{Shoulder bideltoid breadth}$<br>(S=1.32 ; $R^2_{\text{adj}}$ =63.37% ; Durbin-Watson statistic=1.76)                                 |
| <b>Shoulder bideltoid breadth</b>              | $y = 30.13 - 0.03 \cdot \text{age} - 0.10 \cdot \text{job-group} + 0.16 \cdot \text{body mass} + 0.03 \cdot \text{stature}$<br>(S=2.53 ; $R^2_{\text{adj}}$ =43.63% ; Durbin-Watson statistic=1.82) | $y = 10.27 - 0.01 \cdot \text{age} + 0.08 \cdot \text{job-group} - 0.24 \cdot \text{stature} + 0.21 \cdot \text{Eye height} - 0.01 \cdot \text{Sitting height} + 0.10 \cdot \text{Buttock-popliteal length} - 0.03 \cdot \text{Sitting forward thumb-tip reach} + 0.94 \cdot \text{Shoulder biacromial breadth} + 0.09 \cdot \text{body mass}$<br>(S=1.92 ; $R^2_{\text{adj}}$ =67.32% ; Durbin-Watson statistic=1.75) |

Table B.80. Regression model table for all other anthropometric measurements (cont'd).

|                                  |                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|----------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Hand breadth</b>              | $y = 6.68 + 0.01 \cdot \text{age} + 0.07 \cdot \text{job-group} + 0.01 \cdot \text{body mass} + 0.01 \cdot \text{stature}$<br>$(S=0.55 ; R_{\text{adj}}^2=5.94\% ; \text{Durbin-Watson statistic}=1.22)$   | $y = 0.24 + 0.01 \cdot \text{age} + 0.01 \cdot \text{job-group} + 0.01 \cdot \text{Fingertip height} + 0.01 \cdot \text{Waist height} - 0.02 \cdot \text{Forward grip reach} + 0.23 \cdot \text{Foot breadth} + 0.01 \cdot \text{Sitting vertical fingertip reach} - 0.03 \cdot \text{Head circumference} + 0.08 \cdot \text{Head length} + 0.08 \cdot \text{Bizygomatic (face) breadth} + 0.015 \cdot \text{Chest circumference} + 0.01 \cdot \text{Hip breadth (sitting)} - 0.14 \cdot \text{Hand length} + 0.12 \cdot \text{Palm length perpendicular} + 0.30 \cdot \text{Index finger length} + 0.15 \cdot \text{Hand circumference} - 0.01 \cdot \text{Wrist circumference}$<br>$(S=0.36 ; R_{\text{adj}}^2=60.02\% ; \text{Durbin-Watson statistic}=1.43)$ |
| <b>Palm length perpendicular</b> | $y = 4.63 + 0.01 \cdot \text{age} + 0.06 \cdot \text{job-group} + 0.01 \cdot \text{body mass} + 0.03 \cdot \text{stature}$<br>$(S=0.55 ; R_{\text{adj}}^2=17.07\% ; \text{Durbin-Watson statistic}=1.42)$  | $y = 2.16 - 0.02 \cdot \text{Chest (bust) depth} + 0.02 \cdot \text{Sitting height} - 0.01 \cdot \text{Popliteal height} + 0.01 \cdot \text{Sitting vertical thumb-tip reach} - 0.02 \cdot \text{Head circumference} + 0.091 \cdot \text{Menton-sellion (face) length} - 0.12 \cdot \text{Bizygomatic (face) breadth} + 0.02 \cdot \text{Chest circumference} + 0.29 \cdot \text{Hand length} + 0.09 \cdot \text{Hand circumference} - 0.09 \cdot \text{Wrist circumference}$<br>$(S=0.43 ; R_{\text{adj}}^2=49.15\% ; \text{Durbin-Watson statistic}=1.41)$                                                                                                                                                                                                     |
| <b>Index finger length</b>       | $y = 2.36 + 0.01 \cdot \text{age} + 0.03 \cdot \text{job-group} + 0.01 \cdot \text{body mass} + 0.03 \cdot \text{stature}$<br>$(S=0.50 ; R_{\text{adj}}^2=12.42\% ; \text{Durbin-Watson statistic}=1.14)$  | $y = 0.58 + 0.01 \cdot \text{age} + 0.06 \cdot \text{job-group} - 0.01 \cdot \text{Fingertip height} - 0.01 \cdot \text{Waist height} - 0.04 \cdot \text{Foot length} + 0.02 \cdot \text{Sitting height} + 0.01 \cdot \text{Knee height} + 0.01 \cdot \text{Buttock-leg length} - 0.08 \cdot \text{Bizygomatic (face) breadth} + 0.34 \cdot \text{Hand length}$<br>$(S=0.36 ; R_{\text{adj}}^2=53.38\% ; \text{Durbin-Watson statistic}=1.59)$                                                                                                                                                                                                                                                                                                                   |
| <b>Hand circumference</b>        | $y = 11.94 + 0.04 \cdot \text{age} - 0.02 \cdot \text{job-group} + 0.05 \cdot \text{body mass} + 0.02 \cdot \text{stature}$<br>$(S=1.52 ; R_{\text{adj}}^2=19.90\% ; \text{Durbin-Watson statistic}=0.89)$ | $y = 10.61 + 0.02 \cdot \text{age} + 0.10 \cdot \text{job-group} + 0.03 \cdot \text{body mass} - 0.027 \cdot \text{Waist circumference} + 0.43 \cdot \text{Wrist circumference} - 0.02 \cdot \text{Shoulder-fingertip length} + 0.10 \cdot \text{Neck circumference}$<br>$(S=1.30 ; R_{\text{adj}}^2=42.36\% ; \text{Durbin-Watson statistic}=0.85)$                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Wrist circumference</b>       | $y = 2.22 + 0.04 \cdot \text{age} - 0.14 \cdot \text{job-group} + 0.05 \cdot \text{body mass} + 0.06 \cdot \text{stature}$<br>$(S=1.63 ; R_{\text{adj}}^2=24.59\% ; \text{Durbin-Watson statistic}=0.82)$  | $y = -3.03 + 0.01 \cdot \text{age} - 0.11 \cdot \text{job-group} + 0.42 \cdot \text{Hand circumference} - 0.32 \cdot \text{Hand breadth} + 0.66 \cdot \text{Hand length} + 0.03 \cdot \text{Waist circumference} - 0.05 \cdot \text{Hip breadth (sitting)} + 0.02 \cdot \text{body mass}$<br>$(S=1.26 ; R_{\text{adj}}^2=54.92\% ; \text{Durbin-Watson statistic}=1.07)$                                                                                                                                                                                                                                                                                                                                                                                         |

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