MUSCULOSKELETAL SYMPTOMS AMONG MUSICIANS: INDIVIDUAL AND INSTRUMENT USE-RELATED RISK FACTORS AND INTERFERENCE WITH MUSICAL PERFORMANCE

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ABSTRACT

MUSCULOSKELETAL SYMPTOMS AMONG MUSICIANS: INDIVIDUAL AND INSTRUMENT USE-RELATED RISK FACTORS AND INTERFERENCE WITH MUSICAL PERFORMANCE

Playing a musical instrument requires force exertion by different muscles at different positions depending on the musical instrument type. Moreover, during a musical performance, muscle coordination with the rhythmic pattern of the music should be maintained while expressing the emotion in the musical piece. Since ergonomics doesn't have an effect in musical instrument design process as sound production has, musicians might encounter musculoskeletal discomfort and disorders while using their muscles to play musical instruments. The aims of the study were to investigate the prevalence and musical performance interference of musicians' symptoms, analyze the factors affecting them, and develop prevention ideas. For that purpose, data were collected by a developed survey tool from 348 participants consisting of professional and amateur musicians, music teachers and students who were playing instruments from brass, drums and percussion, keyboard, strings, woodwind, and plucked strings instrument families. Moreover, the hand dimensions of 33 participants were measured and RULA Analyses were made to musicians playing instruments from every musical instrument group. The results showed that 98.28% and 66.09% of the participants had symptoms and performance interferences at least at one body part, respectively. Strings and woodwind group instrument players were found to have the highest number of body parts at risk while higher experience levels increased the risk of symptoms and musical performance interferences. Suggestions were made for instrument playing positions to prevent musical instrument playing related symptoms, ergonomic instruments and supportive tools.

ÖZET

MÜZİSYENLERDE KAS-İSKELET SİSTEMİ HASTALIKLARI: BİREYSEL VE ENSTRÜMAN KULLANIMINA YÖNELİK FAKTÖRLER VE MÜZİK PERFORMANSINA ETKİSİ

Müzik aleti çalmak için vücudun farklı kasları aracılığıyla enstrüman tipine bağlı olarak değişken pozisyonlarda kuvvet uygulanması gerekir. Bununla birlikte, bir müzikal performans sırasında, çalınan parçanın ritmine uyum sağlayacak ve parçadaki duyguyu tam olarak aktaracak biçimde kas hareket ve koordinasyonlarının sağlanması gerekmektedir. Müzik aletlerinin tasarım aşamalarında ergonomi ses üretimi kadar önem taşımadığı için müzisyenlerin müzik aletlerini çalmak için kaslarını kullanırken kas ve iskelet sistemi hastalıklarına yakalanma olasılığı bulunmaktadır. Bu çalışmanın amacı, müzisyenlerde enstrüman çalma sebebiyle görülmekte olan rahatsızlıkların yaygınlığı ve müzikal performansa olan etkisini araştırmak, bunlarda etkili faktörleri ortaya çıkararak rahatsızlıkları engelleme önerileri belirtmektir. Çalışma kapsamında bahsedilen amaçları gerçekleştirmek için tuşlu, vurmalı, yaylı, telli, tahta üflemeli ve bakır üflemeli çalgı gruplarından müzik aletleri çalan profesyonel ve amatör müzisyenler, müzik öğretmenleri ve öğrencilerinden oluşan 348 katılımcıdan veri toplanmıştır. Bununla beraber, 33 katılımcının el ölçüleri ölçülmüş ve her enstrüman grubuna çalma pozisyonlarını analiz etmek amacıyla RULA analizi uygulanmıştır. Çalışma sonuçları katılımcılarının %98,28'inin en az bir vücut bölümünde semptomlara rastlandığını ve %66,09'sının da en az bir vücut bölümünde müzikal performansının etkilendiğini göstermiştir. Yaylı grup çalgılar ve tahta üflemeli çalgılar en fazla risk taşıyan vücut bölümlerine sahip enstrüman grubu olarak bulunmuş ve uzun yıllardır enstrüman çalan müzisyenlerin diğer müzisyenlere göre daha yüksek olasılıkla kas-iskelet sistemi rahatsızlıkları ile karşılaşarak müzikal performanslarının daha fazla etkilenebileceği belirtilmiştir. Kas-iskelet sistemi rahatsızlıklarının önüne geçmek için enstrüman çalma pozisyonları ile ergonomik müzik aletleri ve yardımcı araçların tasarımı ile alakalı tavsiyeler verilmiştir.

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A_n^2	Anderson-Darling test statistic
C_1	Coefficient for scaling mean
C_2	Coefficient for scaling standard deviations
$cov(X, Y)$	Covariance of variables X and Y
F_i	Frequency at ith body part
$F^*(X_i)$	Cumulative distribution function
FN	Number of false negatives
FP	Number of false positives
H_{test}	H-test statistic to be used when there are ties
H_{test*}	H-test statistic to be used when there are no ties
$L(\hat{t})$	Maximized log-likelihood function
log(Y)	Logarithmic transformation of the dependent variable Y
K	Number of random samples
MPI_i	Musical performance interference at ith body part
$MPIB_i$	Musical performance interference binary operator for ith body part
$MPIR_i$	Musical performance interference ratio at ith body part
m	Number of multiple comparisons
N	Number of negatives
N_T	Total number of observations
n	Sample size
n_i	Sample size of sample i
$n_{MPIB_i=1}$	Number of participants having performance interference at ith body part

$n_{PB_i=1}$	Number of participants having symptoms at ith body part
n_p	Number of parameters in the model
$n_{TBMPI=1}$	Number of participants having total body performance effect of 1
$n_{TBP=1}$	Number of participants having total body prevalence of 1
n_t	Total number of participants
$n_{(-)}$	Sample size of negatives
$n_{(+)}$	Sample size of positives
P	Number of positives
p	Probability of event happening
PB_i	Prevalance binary operator for ith body part
PR_i	Prevalence ratio at ith body part
R_0	Negative samples' sum of ranks
R_X	Rank of variable X
R_Y	Rank of variable Y
r_{ij}	Rank of each variable
r_p	Pearson correlation coefficient
r_s	Spearman's correlation coefficient
S_i	Severity at ith body part
S_r^2	All ranks' mean sum of square value
S_t^2	Sum of square of each level
sqrt(Y)	Square root transformation of the dependent variable Y
t_c	t-value for correlation significance calculation
$TBMPI$	Total body musical performance interference
$TBMPIR$	Total body performance interferenc ratio

TBP	Total body prevalance
$TBPR$	Total body prevalance ratio
$TBWS$	Total body weighted score
TN	Number of true positives
TP	Number of true positives
V_i^2	Sample variance of population i
WS	Weighted score
WS_i	Weighted score at i^{th} body part
$X_1, X_2, \dots, X_n$	Independent variables
X_i	Ordered data
α	Intercept
$\beta_1, \beta_2, \dots, \beta_n$	Regression coefficients
χ_0^2	Bartlett's test statistic
$\mu_{X1}, \mu_{X2,} \mu_{Y1}$	Means of the known parameters of the first and second population
μ_{Y2}	Mean of the unknown parameter of second population
π^*	Adjusted p-value of the comparison
π	p-value of the comparison
σ_X	Standard deviation of variable X
σ_Y	Standard deviation of variable Y
$\sigma_{X1}, \sigma_{X2}, \sigma_{Y1}$	Standard deviations of the known parameters
σ_{Y2}	Standard deviation of the unknown parameter of second population
$\sigma_1^2, \sigma_2^2, \dots \sigma_k^2$	Variance of each sample from 1 to k

LIST OF ACCRONYMS/ABBREVIATIONS

AIC	Akaike Information Criterion
ANOVA	Analysis of Variance
AUC	Area under the Receiver Operating Characteristics graph
BMI	Body-mass index
CTD	Cumulative trauma disorder
DASH	Disabilities of arm, shoulder and hand
EMG	Electromyography
HS	Hand span
MLE	Maximum Likelihood Estimation
MSD	Musculoskeletal disorder
NIOSH	National Institute for Occupational Safety and Health
ROC	Receiver Operating Characteristics
RULA	Rapid Upper Limb Assessment
SD	Standard Deviation

1. INTRODUCTION

Musical instruments are being used for a long time for different purposes. Voice of human is considered to be the first instrument used, after some time people started to invent musical instruments to support their voice (Paganelli, 1970). The musical instrument designs evolved in time and they are now being played by professional or amateur musicians, fresh starters to music educations, and other people for musical performance, education, training, teaching, entertainment purposes as well as for musical therapy, and leisure time activity. Since musical instruments were developed with an aim to produce required sounds, design principles of ergonomics were not taken into consideration as an important factor during their design process. Nevertheless, the lack of ergonomics in the design and use of the musical instruments might cause musculoskeletal symptoms or disorders for the musicians during instrument playing.

For the musicians, having musculoskeletal symptoms and disorders is an important issue since they might affect the ability to play, which is a crucial element for making music. A musician's musculoskeletal system may be affected by factors which are not related with music, however, the factors related with music should be carefully evaluated in order to prevent possible symptoms or injuries during playing. León *et al.* (2015) stated that the elements which result in musculoskeletal disorders of the musicians are inadequate posture of the body parts, strain due to playing, making the same motion plenty of times or for long period of time, static force acting on the musicians' body due to awkward posture such as violists' neck or a musicians' body while sitting, and the effect of the instrument parts' human body coming in contact; such as guitar's strings and other surfaces which are in contact with the fingers and hands of the musician. As expressed by Quarrier (1993), exercising for lengthy durations, not having a good form of the body and inadequate posture causes a remarkable amount of musical instrument playing related disorders.

Musical instrument playing is an activity that requires muscle usage in different body postures according to the musical instrument type used. While playing a musical instrument, musicians pay attention to the movements of their hands, fingers or other body parts in order to maintain the musical pattern they shape in their brains. Musicians are

more concentrated for their musical performance and musical instrument playing than being cautious about the playing-related injuries. Moreover, Quarrier (1993) stated that musicians should be considered as people involved in sports and added that dexterity, adaptability and orientation, which are the elements that are required in sports, are needed for musicians during their activities performed. For instance, musicians need to use their body in order to play the notes of a musical piece in the requested velocity, force and harmony. To achieve this, musicians should be in good condition by making practice. Secondly, musicians should continuously feel the musical piece they are playing during performance to maintain the emotional pattern in the music and express the feeling in the best way. Since the concentration for playing perfectly and emotionally is necessary, musicians might not take precautions against being injured while playing. Thus, spending too much effort on playing correctly and emotionally may result in over-use syndromes of their muscles.

The main purpose of this study is to investigate the factors affecting musical instrument playing symptoms, find out the body parts which are at risk, and come up with prevention ideas.

In this study, there are seven chapters including introduction. In Chapter 2, literature review about the studies made for musical instrument playing related symptoms or injuries were explained, their results and methods were evaluated. Chapter 3 includes the rationale and the objectives of the study and Chapter 4, which is the methodology section, consists of methods explained such as survey tool to collect the data, hand dimensions measurements, and the statistical analyses. Chapter 5 includes the statistical analysis performed as well as the suggestions of the musicians for better performance and instrument designs and Chapter 6 consists of the discussion of the study results and their comparisons with other studies. Moreover, in Chapter 6, the prevention ideas of the study are explained. Lastly, Chapter 7 is the conclusion section in which all the results of the study with limitations and recommendations are explained.

2. LITERATURE REVIEW

2.1. Musculoskeletal Disorders

In daily life, people perform some physical activity for the tasks needed to be completed. During the physical activity performed, people use their muscles, bones, joints and other parts of their body. Basically, if the effort spent during the physical task exceeds the capacity of the human body, there is a risk of musculoskeletal disorders (MSDs). Moreover, MSDs not only develop suddenly due to the excessive amount of strain, they also occur when the human body is affected from a long-time load such as years of working in a factory.

According to NIOSH (1997), cumulative type of MSDs called cumulative trauma disorders (CTDs) develop in time rather than arise from a suddenly occurring event such as tumbling or stumbling. Putz-Anderson (2010) stated that a part of the musculoskeletal system of a working person is injured because of long-term developing problems called CTDs rather than sudden events happening.

MSDs have an important effect on the daily life of the people because they limit some of the movements during daily activities or result in pain. Besides their physical results, MSDs can have mental, economic or social effects. Morse *et al.* (1998) made a study in order to evaluate how people are affected by work related MSDs socially and economically and pointed out that they had difficulty in everyday activities such as looking after a child or taking shower. What's more, they stated that some participants had economic problems, for instance, they had to change the location of their residences, breakup with their wives or husbands or sell their automobiles. Furthermore, MSDs can cause psychological problems. Jenness *et al.* (2017) found that the physical injuries occurred in the past year results in the increased risk of mental disorders of the current month. Thus, it can be concluded that the MSD occurrence can have a result of mental illnesses or it can affect the people socially or economically besides its physical consequences.

People can encounter different musculoskeletal problems since they complete plenty of tasks every day for daily life events or their jobs. Gerr *et al.* (2002) found out that the musculoskeletal symptoms and disorders among computer users were frequent. In the study made in order to evaluate the work-related MSDs in a group of physical therapists, Bork *et al.* (1996) stated that the most frequently affected body areas were bottom and upper part of the back, hands and wrists and neck

In order to avoid MSDs, the risk factors in the work environment should be reduced or eliminated. There are various risks in different tasks. For instance, Long *et al.* (2012) made a review in order to evaluate the possible risks of the work-related disorders and their results for the health care personnel such as physicians, childbirth assistants, and nurses, and found out that the time pressure of the work and hazards in physical activities were the most important factors affecting MSD's. Tittiranonda *et al.* (1999) expressed that various research made so far stated that the risks for the work-related MSDs to be inadequate posture, vibration, strain at the limits of the body and recurrent movements. Moreover, in the study made by Leea and Choub (2010), it is pointed out that the tasks which make a person work in hard conditions and use machines enhanced the risk of injuries at the face. What's more, Walker-Bone and Palmer (2002) stated that farm workers have unexpected injury risk during work. By knowing the risk factors in each profession, the occurrence of MSDs can be prevented.

2.2. Musculoskeletal Symptoms and Injuries of the Musicians

In order to play a musical instrument in the required rhythm and express the feeling in the musical piece, musicians use their hands, fingers, arms, shoulders, legs or other parts of their bodies. Musicians should maintain coordinated movements of all body parts needed to play the instrument which requires attention and practice. Musicians' bodies are affected by different workloads during musical instrument playing. Due to the strain while playing an instrument, musicians can get injured or they can feel discomfort at their body parts. Chan and Ackermann (2014) summarized the factors that cause risk of musical instrument playing related injuries and grouped them according to being physical or psychological and social (Table 2.1).

Table 2.1. The physical, social and psychological risk factors affecting playing related MSDs. (Chan and Ackermann, 2014; Brandfonbrener, 2010; Ackerman *et al.*, 2012; Leaver *et al.*, 2011; Altenmüller and Jabusch, 2010; Kenny and Ackermann, 2013; Wu *et al.*, 2007)

Physical Risk Factors		**Social and Psychological Risk Factors**
Cannot be changed	**Can be changed slightly or completely**	
• Type of musical instrument • Gender • Circumstances of performance such as duration of playing and environmental conditions • The music type or songs played • Previous injury	• Over-exerting muscles while playing • Duration of rest breaks • Inadequate posture • Joint hyperlaxity • Instrument playing style • Lack of fitness • Ineffective injury treatment	• Nervousness during performance • Being in a long term unhappy mood • Stress as a result of school or work environment • Daily life or performance stress • Feeling uncomfortable in society • Somatization

As a result of various risk factors mentioned above, there are diverse playing related disorders among musicians. Liu and Hayden (2002) stated that repeated motions with excessive loads acting on the body and inadequate postures during playing causes overexertion of the muscles, which is one of the common musical instrument playing related discomfort. Liu and Hayden (2002) also expressed that musicians can encounter playing related problems such as focal dystonia, skin discomfort, damage to peripheral nerves, and ear, nose and throat system discomfort. Žuškin *et al.* (2005) stated that different health issues such as dermatologic problems, problems related with ears, muscles, bones, ligaments, and respiration system are associated with the profession and way of life and they make musicians feel pain. Musicians can have discomforts at different locations of their body. In the study by Yeo *et al.* (2002), the problems related with mouth, teeth and face are found as mouth dryness, false teeth holding, herpes on the lips, disorders at joints at the jaw. Laitinen and Poulsen (2008) pointed out that the activity of the musicians is affected by audiological problems which are occurring in musicians' lives.

The playing related musculoskeletal discomfort or injuries can vary according to the instrument type used. Paarup *et al.* (2012) found that the musicians playing in orchestras have discomforts at their necks, shoulders and back parts of their body. Gambichler *et al.*

(2004) expressed that hypersensitivity of the human body while touching instruments and particular discomforts such as violin player's neck are the dermatological problems that exist in instrument groups of strings, wind and brass and added that some musicians' skins can get infected. Plevnik *et al.* (2015) modified and outlined the musculoskeletal disorders related with different musical instruments from the study of Robinson and Zander (2012). The disorders according to the instrument groups and instrument types are given at Table 2.2.

2.3.Studies Made About the Musical Instrument Playing Related Symptoms and Injuries of the Musicians

2.3.1. General Overview of the Studies

In the studies made for evaluation of the musculoskeletal symptoms, injuries and pain among musicians, data were collected from the group of students, professional musicians, music teachers or people who are not related with musical instrument playing. There are common or different data collection methods and instrument types used in the studies. Moreover, number and attributes of participants are different in studies while in some studies same type of the information was collected, for instance, practice time and hand span. The studies made are summarized in Table 2.3. The details about data collection method, musical instrument types included, participants' information, collected data (e.g. demographics, instrument usage per week etc.), and results and conclusions are stated in Table 2.3.

Table 2.2. Musculoskeletal disorders of the musicians according to the instrument groups (Plevnik *et al.*, 2015)

<table>
<tr><th>Instrument Group</th><th colspan="4">Instrument Type</th></tr>
<tr><td rowspan="2">Strings and Plucked Strings</td><td>Guitar</td><td>Violin and viola</td><td colspan="2">Cello and string bass</td></tr>
<tr><td>Tendinits at triceps
Right hand index, middle finger, and thumb focal dystonia
(Left) thoracic outlet syndrome
(Left)Carpal tunnel syndrome
(Left) Flexor carpi ulnaris tendinitis
(Left)dorsal interrosseous overexertion</td><td>Agony of neck (Left)Thoracic outlet syndrome
(Left) Carpal tunnel syndrome
(Left) Cubital Tunnel Syndrome
(Right)Rotator Cuff Tendinitis
(Right) Extensor carpi radialis tendinitis
Disorders at joints at the jaw</td><td colspan="2">Agony of neck (Left)
Ulnar nerve entrapment
(Left) Flexor carpi ulnaris tendinitis
(Right) Rotator cuff tendinitis
(Right) Extensor radialis tendinitis</td></tr>
<tr><td>Keyboard</td><td colspan="4">Piano, organ and accordions
Thoracic outlet syndrome
Medial and lateral epicondylitis
Tendinitis of wrist flexors and extensors
Carpal tunnel syndrome
De Quervain’s syndrome
Dorsal wrist ganglion
Thumb, finger, hand, and foot muscles focal dystonia</td></tr>
<tr><td rowspan="4">Woodwind</td><td>Flute</td><td>Bassoon</td><td colspan="2">Clarinet</td></tr>
<tr><td>(Left and Right) Thoracic outlet syndrome
(Left) Ulnar nerve entrapment
(Left) Extensor carpi radialis tendinitis
Agony of neck and back
(Left and Right) De Quervain’s syndrome
Left ring and little fingers focal dystonia</td><td>Agony of neck and back
Disorders at joints at the jaw
Issues with teeth Teres major muscle and the right pectoralis major muscle overexertion
De Quervain’s syndrome</td><td colspan="2">Right Carpometacarpal joint overexertion
Carpal tunnel syndrome
(Right) De Quervain´s syndrome
(Right and Left) Lateral epicondylitis Disorders at joints at the jaw</td></tr>
<tr><td colspan="2">Oboe</td><td colspan="2">Saxophone</td></tr>
<tr><td colspan="2">(Right)Extensor carpi radialis tendinitis
(Right) Lateral epicondylitis
(Right) Ulnar nerve entrapment
(Right) Posterior interosseous nerve entrapment
Agony of neck and back
De Quervain’s syndrome</td><td colspan="2">Agony of neck and back
(Right and left) Extensor carpi radialis tendinitis
Disorders at joints at the jaw</td></tr>
<tr><td rowspan="2">Brass</td><td colspan="2">Trumpet</td><td colspan="2">Trombone</td></tr>
<tr><td colspan="2">Maxillofacial and lip trauma
Pharyngeal dilatation</td><td colspan="2">Lip focal dystonia
(Right) Lateral epicondylitis
Orbicularis oris muscle overexertion</td></tr>
<tr><td>Percussion</td><td colspan="4">Lateral and medial epicondylitis
Flexor carpi ulnaris tendinitis
Extensor carpi radialis tendinitis
De Quervain’s syndrome
Carpal tunnel syndrome
Achilles tendinitis</td></tr>
</table>

Table 2.3. Summary of the studies in literature

Source	Data Collection Method	Musical Instrument Types Included in the Study	Information of the participants	Data Collected	Results & Conclusion
1-Dommerholt (2009a) 2-Dommerholt (2009b)	• Survey • Posture examination • Range of Motion Examination • Instrument-specific examination (pictures)	French Horn Violin Cello Flute Clarinet Double Bass	Male and female; Age and Number of participants are not stated	Instrument type, practice details, education background, repertoire, employment status, injury functional grading Posture, range of motion and instrument specific visual data	It is hard for the musicians to find a healthcare support, so the musician's instrument specific healthcare needs should be well-specified by observing them while playing and medical aid should be given accordingly.
3-Dommerholt (2009c)	• Direct examination • Interview	Organ Bassoon Guitar	3 people: Male college student bassoonist, male amateur guitarist, and female professional organ player having ages of 19, 30, 26 respectively.	Injury Detail Musical background Clinical diagnosis	Physiotherapists should ask special questions to the musicians regarding instrument type, education, practice etc. in order to make better decisions about the treatment strategy. Hypermobility and past-injuries resulted in musical instrument playing related injuries.
4-Berque *et al*. (2014)	• Questionnaire	Orchestral Instruments	101 professional orchestra musicians from Scotland	Age, gender, experience Playing related disorder definition Prevalence (lifetime, in a year, in a month and current pain) Duration, frequency, location of the pain Sleep detail, social problems, instrument-specific problems	The evaluation method explained in the study was stated to be a strong tool to measure playing related injuries.

Table 2.3. Summary of the studies in literature (cont.).

Source	Data Collection Method	Musical Instrument Types Included in the Study	Information of the participants	Data Collected	Results & Conclusion
5-León *et al*. (2015)	• Questionnaire	Violin, contrabass, viola, violincello	55 subjects (20 women, 35 men) between ages 12 and 34; members of youth Band of Zapopan and Guadalajara	Practice habits, symptoms of injury, ergonomic accessories usage, MSD risks knowledge background, being aware of preventive education	Half of the survey group were aware of how to prevent injuries, %77,4 of the survey group warm-up %69.6 of the group doesn't use supportive objects. Music related injury locations changed according to the instrument type. According to the musicians, inadequate posture and technique affects music related injuries. Prevalence result found: 35% at whole body
6-Nawrocka *et al*. (2014)	• Questionnaire • Nordic Musculoskeletal Questionnaire	Strings, keyboard and wind	225 Polish musical school students (138 girls, 87 boys, age range10-18)	Practice frequency and average daily practice time, physical activeness evaluation (without playing a musical instrument), body-part specific pain occurrence history	Among young musicians, occurrence of musculoskeletal pain was expressed to be related with low level of physical activeness. Prevalence result found: 76% at whole body
7-De Smet *et al*. (1998)	• Questionnaire • Hand size measurement • Grip strength measurement • Key pinch strength and pinch strength measurement	Piano	66 pianists (33 women, 33 men) mean age of 22,6 years and 66 people for the control group	Playing habits Musculoskeletal problems Hand size, grip strengths, pinch and key pinch strengths	For both females and males, smaller hands result in overuse musculoskeletal symptoms. Pianists were found to have less pinch and grip strength than the control group. No correlation could be found between playing related disorders and the factors training length, age of start to play, warming-up, playing more than one instruments and making sports.

Table 2.3. Summary of the studies in literature (cont.).

Source	Data Collection Method	Musical Instrument Types Included in the Study	Information of the participants	Data Collected	Results & Conclusion
8-Zaza *et al.* (1998)	• Interview	Strings Keyboard Woodwind Brass	27 musicians (19 females, 8 males), age 18-63	Playing related disorder perceptions, experiences Playing related disorder subjective definitions	More attention should be paid for patients' personal perceptions of playing related disorders in order to reduce risks and take efficient actions.
9-Blanco-Pineiro and Diaz-Pereira (2015)	• Videotape and Photograph examination	Piano, brass, strings, woodwind vocalists, percussion, bagpipe	100 music students (40 females, 60 males) from Spain	Postural analysis from videos and photographs Conservatory grade Years of music study	Even most experienced music students were prone to adapt incorrect postures during performance Sitting students were prone to adapt incorrect postures when compared with the standing students.
10- Steinmetz *et al*. (2010)	• Direct examination	Strings Wind Keyboard	84 musicians (37 males, 47 females)	Postural (lumbar and cervicothoracic) stabilization systems of the patients, age, height, weight, clinical information of local pain, previous therapy regimes, training, body awareness techniques	Most of the musicians examined had postural stabilization problems. String players had more impairment of stabilization systems when compared with the keyboard players and symmetrically played wind instruments.

Table 2.3. Summary of the studies in literature (cont.).

Source	Data Collection Method	Musical Instrument Types Included in the Study	Information of the participants	Data Collected	Results & Conclusion
12-Ackermann, *et al*. (2002)	• EMG • Videotape and audio-recorder for performance	Violin	8 violin players (5 females, 3 males: ages 28 to 47 years)	EMG activity of upper trapezii, the scapula retractors and the right sternocleidomastoid muscles during the performance of 3 pieces.	The scapula taping was found uncomfortable and taping didn't improve feeling of pain or support.
13-Van Vugt *et al.* (2014)	• Questionnaire • Scale Playing Regularity Measurement	Piano	54 Pianists who received treatment at the Movement Disorders Clinic	Type and effectiveness of received treatment Regularity of ascending and descending scale playing with the affected hand	Musicians with dystonia had difficulty during the performances requiring fine motor tasks, however, after a dystonia treatment, musicians can improve their performance.
14- Mishra and Gangopadhyay (2013)	• Nordic Musculoskeletal Questionnaire and questionnaire consisting of questions of 10-point Likert Scale	Tabla	84 Indian Tabla players. Age mean:34.9, standard deviation:11.5	Experience Hours of practice per day Average performances per month Discomfort of body parts (neck, left &right shoulder, lower back) Risk factors resulting in playing related disorders (long practice, insufficient rest etc.)	The main areas of discomfort in the body of Tabla players were lower back and the right shoulder. According to the tabla players, posture and work-related factors had the most effect on the music related playing injuries. Prevalence result found: 67.06% at neck, 74.15% at lower back, 67.06% at right shoulder.

Table 2.3. Summary of the studies in literature (cont.).

Source	Data Collection Method	Musical Instrument Types Included in the Study	Information of the participants	Data Collected	Results & Conclusion
16-Furuya, *et al.* (2006)	• Questionnaire	Piano	203 Japanese female classical pianists, age range 15-60	The starting age to the piano, total number of years played, frequency and average duration of practice, average rest period during practice Difficulty of covering octave keys, subjective evaluation of upper extremity strength in daily life, piano type used for practice, playing related disorder locations on body	Pianists should be educated about injury prevention during practice Hand size was not a direct factor for playing related disorders. Age was found to have an effect on the musical instrument playing related injuries. Long daily practice, enjoying practice and being anxious in daily life increases the risk of playing related injuries. Prevalence result found: %77 at whole body
17-Ranelli *et al.* (2011)	• Questionnaire	Piano Strings Woodwind Guitar Harp Percussion	731 children (460 females, 271 males) studying instrumental music in Perth, Australia, age range 7-17	Experience of playing related disorders Location of pain Experience, type of instrument as main, second or third, years spent playing Recorded type and duration of playing (rehearsals etc.) and breaks Personal attributes, hand dominance, general musculoskeletal complaints, general habits	The factors gender, age, playing time and type of instrument were found related with the musical instrument playing related injuries. Parents and teachers should be warned of the high prevalence of the playing related disorders among children and they should take precautions. Prevalence results: 56% at whole body, 24% and 23% at left elbow and hand, 16% at neck. Musical performance interference results: 30% at whole body
18-Kok *et al.* (2013)	• Questionnaire (Electronic)	Strings (bowed and plucked) Woodwinds Brass Percussion Keyboards	Total of 3215 students: 345 students from three music academies, 2870 students from one medical school, age mean:21.5, SD:2.2	Musculoskeletal discomfort in last twelve months and at the time of questionnaire Socio-demographic factors Occurrence of musculoskeletal complaints in 6 body regions	Musicians had more musculoskeletal complaints when compared with non-musicians especially for the upper-extremities. Prevalence result found: %89.12 at whole body

Table 2.3. Summary of the studies in literature (cont.).

Source	Data Collection Method	Musical Instrument Types Included in the Study	Information of the participants	Data Collected	Results & Conclusion
19-Paarup *et al.* (2012)	• Questionnaire including Nordic Musculoskeletal Questionnaire and Borg Scale • Clinical analysis • Interview	Strings Wind Percussion	441 musicians from 6 Danish symphony orchestras, age range 20-79	Self-reported symptoms of pain of body parts in previous week Clinical findings in the neck, back and limbs. (Range of motion, hypermobility, discomfort grade etc.)	Different type of data collection techniques should be used as well for other studies for evaluating musculoskeletal problems in musicians. Discomfort was mostly found on neck, back and shoulders. Prevalence result found: 64.8% at neck, 52.8% at left shoulder, 50% at right shoulder
20-Paarup *et al.* (2011)	• Questionnaire	Strings Wind Percussion	342 musicians (208 men 134 women) from 6 Danish symphony orchestras	Prevalence in seven days and twelve months Symptom duration Playing exposure, music education, current employment	During the last one year %97 of the women and %83 of men experienced symptoms in at least one of the body parts. Females were found to have more risk of having musical instrument playing related discomforts.
21-Guptill (2011)	• Interview • Focus group	Violin Cello Harp Flute Percussion Trumpet	10 professional musicians from Ontario, Canada	Time and details of injury Feelings and thoughts about injury Activities done in order to overcome injury	Musicians should develop individual injury overcoming methods. Healthcare professionals should be aware of the challenges experienced by musicians.

Table 2.3. Summary of the studies in literature (cont.).

Source	Data Collection Method	Musical Instrument Types Included in the Study	Information of the participants	Data Collected	Results & Conclusion
22-Frucht (2015)	• Video	Violin, Guitar Piano, Organ Drums, Tabla Saxophone Hybrid instrument: Banjo-Guitar	100 patients from a clinic who have Focal Task Specific Disorders	Videos of musicians while instrument playing	An approach was developed for the Focal Task Specific Disorders which are complex injuries. However, more research was needed for the care of the patients.
23-Knapik, *et al.* (2007)	• Questionnaire • Focus group	Strings Winds Keyboard Vocal Percussion Brass	205 members of US Army Band, age mean:39.4, SD:7.8	Physical attributes Practice time Physical activity Smoking Medical care	The risk of being affected by musical instrument playing injuries was found to be correlated with high body mass index, less physical activity, prior injury and practice duration. Prevalence result found: %53 at whole body
24-Rickert *et al*. (2013)	• Interview	Cello	10 professional cellists (6 males, 4 females) from an Australian orchestra + 5 orchestral management staff (3 males, 2 females)	**Psychosocial factors**: Performance stress Interpersonal relationships between orchestra staff Work organization and lack of control	Psychosocial factors, which are out of control of musicians, had essential effects on musicians' health. Stress was found to be an important factor that affects musicians' musical instrument playing injuries.
25-Andersen *et al*. (2013)	• Interview • Concert and rehearsal observation	Viola, Violin, Cello Flute Bass	8 musicians + 2 elite athletes (soccer and handball) (5 males, 5 females)	Information about breaks during concert and rehearsals Feedback of pain during performance	During the healthcare process of the musicians, their life conditions should be well evaluated.

Table 2.3. Summary of the studies in literature (cont.).

Source	Data Collection Method	Musical Instrument Types Included in the Study	Information of the participants	Data Collected	Results & Conclusion
26- Sandell *et al.* (2009)	• Survey (University of Texas Musician Health Survey)	Keyboard, auxiliary and other percussions	279 percussionist musicians (Age mean:28, SD:9.7)	Musculoskeletal problems Non-musculoskeletal problems, Lifestyle and environment	The keyboard percussionists had the highest prevalence of playing related disorders among percussionists, and the body parts which had the highest prevalence of playing related disorders were bilateral hand and low back. Stress and age were found to be the affecting factors for playing related musculoskeletal disorders. Prevalence result found: 77% at whole body
27- Plevnik *et al.* (2015)	• Questionnaire	Strings Plucked Strings Wind Brass Percussion Keyboard instruments	43 students (31 females and 12 males, age mean16.7, SD:1.5) &15 teachers (7 females and 8 males, age mean:36.9, SD:8.8) from Koper Art School	Habits of playing, music traditions Lifestyle information Anxiety, fatigue and injury information Instrument playing approach, medical sensitivity of musicians	Teachers were more aware of the importance of physical activity and they had lower anxiety and pain when compared with students. Preventive methods for injury should be followed during teaching.
28- Fry (1987)	• Interview	Keyboard Woodwind Strings Brass Percussion	1247 students (562 males, 687 females) from 7 music schools in Australia.	Site of pain Duration of history Grading of severity of overuse	The genetic factors, the technique of the student and the practice habits of the student resulted in overuse injury. Students playing woodwind instruments were the mostly playing related injuries-affected group.
29- Stanhope *et al.* (2014)	• Online survey	Woodwind	13 students at the age of 18+ which are undergraduates at university or taking professional education	Playing related injury areas Injury management strategy	62% of the students reported playing related injuries. The body regions mostly affected were hands, lower back and neck.

Table 2.3. Summary of the studies in literature (cont.).

Source	Data Collection Method	Musical Instrument Types Included in the Study	Information of the participants	Data Collected	Results & Conclusion
30-Kok *et al.* (2013a)	• Questionnaire	Strings (bowed and plucked) Woodwinds Brass Percussion Keyboards	Total of 3215 students: 345 students from three music academies, 2870 students from one medical school	Sociodemographic characteristics Smoking habits, sports, alcohol consumption, body-mass index, Body-specific musculoskeletal complaints Illness perceptions	Perceptions of the music students were reported to be more negative when compared with the medical students. Treatment was better controlled in music students than the students in medical school.
31- Jepsen (2014)	• Physical examination	Woodwind	A 55-year-old male musician	Strength of the muscles Neurological response of the body parts	The risk factors of playing bassoon were similar to the risk factors at the industry. After treatment, the musician was able to continue playing normally.
32- Ioannou and Altenmüller (2014)	• Questionnaire • The competitive Trait Anxiety Inventory (Brand, Ehrlenspiel, and Graf, 2009)	Keyboard Strings Woodwind Brass Plucked Strings Percussion	For the 1st study: 24 healthy musicians and 24 focal-dystonia affected musicians, For the 2nd study: 35 focal-dystonia affected musicians	Age, gender Age started playing the instrument, affected hand, hours of experience, musical genre, occupation Psychological symptoms during performance	Musicians who were suffering from focal hand dystonia were more likely to be classified as high-psychologically affected musicians. The number of low-psychologically affected musicians among focal hand dystonia-affected musicians were equal to the high-psychologically affected musicians.
33-Chimenti *et al.* (2013)	• Online questionnaire	Strings Keyboard Brass Woodwind Plucked Strings	261 members from International Conference of Symphony and Opera Musicians, age range: 22-75	Playing history Injury detail Treatment detail Injury related factors	Most of the orchestral musicians didn't report their playing related symptoms because the perceived seriousness of the symptoms was not emerging. Prevalence result found: 93% at whole body

Table 2.3. Summary of the studies in literature (cont.).

Source	Data Collection Method	Musical Instrument Types Included in the Study	Information of the participants	Data Collected	Results & Conclusion
34-Chen *et al.* (2000)	• Pressure algometer for measuring pressure pain threshold	Piano	40 students who have taken at least one year of piano lesson (Age: 8-19)	Three consecutive measurements of Pressure Pain Threshold 20 min before, immediately before, immediately after and 20 min after 20 minutes practice of fast music pieces	The mean pain threshold decreased just after the end of the practice and returned to normal values 20 min after practice. Satisfactory rest might be essential to avoid the development of active myofascial trigger points.
35-Iñesta *et al.* (2008)	• Pulsometer	Strings, wind Piano, percussion Classical Indian instruments	62 professional musicians (20 women, 42 men)	Heart Rate	The cardiac activity of the musician was higher than the activity during the activities made while sitting. The activity was higher in concerts than rehearsals.
36-Altenmüller *et al.* (2012)	• Patient files evaluation	Keyboard, strings, plucked instruments, woodwind, brass, percussion	591 patients from the clinic of the Institute of Music Physiology and Musicians' Medicine of the Hanover University of Music, Drama and Media	Diagnosis, symptom description and location handedness information retrieved from the patient files	There was a higher risk of musculoskeletal symptoms of brass, guitar and woodwind players than the other musicians. The young instrument learners should be taught with attention in order to avoid musculoskeletal injury while playing. Male musicians were found to have higher risks of having playing related musculoskeletal injuries when compared with female musicians.
37-Raymond *et al.* (2012)	• Online Survey	Plucked Strings Wind Brass	32 participants of an orchestra at southwestern United States	Hours per day of practice Illness / injury experience Hazards in work environment Protective device using history	Young musicians were not aware of music-related injuries. Musicians know they are injured, however, they do not spend effort to look for treatments.

Table 2.3. Summary of the studies in literature (cont.).

Source	Data Collection Method	Musical Instrument Types Included in the Study	Information of the participants	Data Collected	Results & Conclusion
38-Rickert *et al*. (2012)	• Questionnaire • Physical Test	Cello	47 professional cellists from 8 orchestras and 25 student cellists from two institutions	Physical profiles, exercise Playing habits Range of motion, rotator cuff dysfunction, trigger point sensitivity	Both students and professional cellists had right shoulder pain which is the most common injury among the groups. Two groups had different playing behavior and daily habits. Female musicians had more recurrent playing related discomfort than male musicians. The playing related injuries were found to be related with trigger point discomfort in musicians.
39- Levy *et al*. (2009)	• Questionnaire	Drum and bugle corp	155 drum and bugle corp performers (130 males, 25 females)	Personality variables (agreeableness, emotional stability, extraversion, openness) Self-reported injury index	Musicians who were open-minded had high risks of having music related injuries. Sentimentally stable musicians had less probability of having playing related injuries. More effort should be spent in order to prevent injury.
40-Chan *et al*. (2013)	• Triage sessions	Strings Brass Woodwind Percussion Harp Keyboard	84 professional orchestral musicians (35 males, 48 females)	Injury location Injury history Injury service evaluation	In order to enhance the quality of the injury management for the musicians, more specific health services should be provided to musicians.
41-Barton *et al*. (2008)	• Questionnaire (DASH and another survey is used)	Woodwind Piano Percussion Strings Brass	97 musicians from collage (52 males, 45 females, age range: 17-27)	Arm, shoulder and hand injury detail Practice habits Height and weight Work and daily habits Education of prevention of injury	Preventive education to students should be provided by the health staff in order to prevent injuries. Gender and instrument type were found related with the musical instrument playing related musculoskeletal discomfort. Prevalence result found: 64.9% at whole body

Table 2.3. Summary of the studies in literature (cont.).

Source	Data Collection Method	Musical Instrument Types Included in the Study	Information of the participants	Data Collected	Results & Conclusion
42-Ackermann and Driscoll (2010)	• Questionnaire	Not stated	350 musicians	Performance frequency Practice information Amount of effort required under different conditions Workdays missed because of injury Injury detail Past injury recovery detail	Questionnaire developed in the study could be easily filled by the subjects. Questionnaire design should be appropriate for providing functional information to the future studies.
43-McCready and Reid (2007)	• In-depth interview	Trombone Trumpet Cello Bass Saxophone Piano	7 music students from university or arts high school (2 females, 5 males: age mean 18.4 years)	Instrument and playing details A day in life Injury coping strategies Suggestions for other students	The meaning of the injuries should be perceived well by the health care side and the issues that music students encounter should be well understood in order to achieve better performance of the music students.
44-Brusky (2010)	• Online Questionnaire (International Bassoonist Questionnaire)	Bassoon	166 bassoonists (96 males, 70 females)	Diagnosis of the injury Injury location Injury duration Number of medical services consulted and treatments tried Practice details	Female bassoon players had greater prevalence of playing related injuries and more of the body parts were affected when compared with male players.
45-Guptill *et al*. (2005)	• Survey with open-ended questions	Not stated	98 students	Suggestions about treatment	In order to satisfy the treatment demands of the injured students, more attention should be paid and health personnel should be specialized for music related injuries.

Table 2.3. Summary of the studies in literature (cont.).

Source	Data Collection Method	Musical Instrument Types Included in the Study	Information of the participants	Data Collected	Results & Conclusion
46-Sadeghi *et al.* (2004)	• Interview • Physician evaluation	Daf and Setar (Iranian Instruments)	78 musicians and 12 students	Daily practice information, Years of played Range of motion Muscle power and reflexes	Iranian musicians had high prevalence of cumulative trauma disorders. More studies are needed to define the important factors.
47-Kaufman-Cohen and Ratzon (2011)	• Questionnaire • Standardized Nordic Questionnaire • DASH questionnaire • RULA	Strings and wind	59 musicians (39 strings, 20 wind), age range 26-66	Weekly and daily practice detail Number of years played Instrument weight Minutes spent for warming up RULA for left/right upper limb	RULA difference was found to be related with upper extremity playing related injuries. It was stated that the average playing hours in a week, instrument weight, observed physical environmental risks and biomechanical risks were related with instrument playing related injuries. Prevalence results found: 39% at neck, 42% at upper back, 55% at shoulders, 49% at lower back
48-Nyman *et al*. (2007)	• Questionnaire	Strings and wind	235 musicians from 12 Swedish music orchestras (Age mean:40, SD: 10)	Years of work Type of orchestra played Off-work instrument playing information Work detail Effect of musical performance Social assistance at work	None of the investigated factors was found to have an effect on pain at shoulder and neck. Higher prevalence of neck and shoulder pain was found at the playing position of elevated arm when compared with the neutral position of playing. Prevalence result found: 25.5% at neck and shoulders
49-Ohlendorf *et al.* (2017)	• 3-Dimensional postural analysis by using video raster stereography • Sitting pressure distribution measurement	Not Stated* (Strings and other instruments)	66 musicians (age range 18-65)	3-dimensional body posture analysis Sitting force distribution	The method used in the study is an effective way to be used for musicians' chair choices.

Table 2.3. Summary of the studies in literature (cont.).

Source	Data Collection Method	Musical Instrument Types Included in the Study	Information of the participants	Data Collected	Results & Conclusion
50-Lai, *et al.* (2015)	• Motion analysis system • Pressure measurement sensors	Piano	20 pianists	Range of Motion Wrist extension and flexion Angle measurement of the fingers while playing	Pianists having smaller hand span are more likely to have playing related symptoms.
51-Gohil *et al.*, (2016)	• Questionnaire • Cornell musculoskeletal disorders questionnaire	Keyboard, guitar, table, harmonium, mouth organ, flute	50 subjects (age range 10-40 from music schools in Ahmedabad	Demographics Frequency and severity of the pain for all body parts	The prevalence of music related injuries was found to be %18 among the subjects. The amount of time spent using the instrument in a month was found to be negatively correlated with instrument use-related symptoms and time spent using the instrument in a week was pointed out to have a slight negative correlation with the playing related symptoms.
52-Zaza and Farewell, (1997)	• Questionnaire • Hand span measurement • Hypermobility measurement	Plucked Strings Strings Keyboard	281 music students and professional musicians who are classically trained and from Ontario	Demographics, physical information Psychological information Practice habits Habits not related with music Hand span, hypermobility	Essential factors found to affect playing related disorders were occupation and daily-life related stress and hypermobility. Body-mass index, gender, instrument type, years of playing were found to have importance in disorders as well. Female players and musicians playing string instruments had higher risk of playing related disorders.
53-Larsson *et al.* (1993)	• Questionnaire • Joint examination	Strings Wind Percussion Keyboard	660 musicians (300 females, 360 males)	Hypermobility of the joints of participants Duration of playing Symptom detail	The hyperlaxity had advantages against musician symptoms for the joints which are in recurrent movements, however, it had disadvantages for the joints which are not moving so much.

Table 2.3. Summary of the studies in literature (cont.).

Source	Data Collection Method	Musical Instrument Types Included in the Study	Information of the participants	Data Collected	Results & Conclusion
54-Lamontagne and Bélanger, (2012)	• Questionnaire	Strings Woodwind Brass	31 musicians (%71 women)	Discomfort-performance interference Discomfort severity Discomfort occurrence	The questionnaire developed is a strong tool except the section related with discomfort's occurrence details.
55-Sakai *et al*. (2006)	• Hand span measurement • Marker detection system with video	Piano	10 pianists (ages: 24-39)	Hand span Thumb, little finger abduction angle while playing chords and octaves	Pianists who have small hand span need to flex their fingers much more than pianists having large hand span, which results in much more risk of having instrument playing related disorders.
56-Fjellman-Wiklund and Edling (2009)	• Questionnaire	Strings Wind Keyboard Trumpet	47 music teachers (28 females, 19 males)	Playing related disorder location Playing related disorder occurrence Instrument use in a week	Playing asymmetric musical instruments resulted in more musculoskeletal discomfort at back and shoulder when compared with the symmetrically played instruments. Female instructurers had more discomfort at their necks and shoulders.
57-Leaver *et al.* (2011)	• Questionnaire	Strings Wind Brass	243 musicians from six British symphony orchestras (Age range 23-64)	Hours of working Information about being prone to somatizing disorders Performance nervousness Working conditions	Somatizing disorders were found related with playing related discomforts. Women feeling themselves bad had more probability of playing related discomfort. Prevalence result found: 86% at whole body

Table 2.3. Summary of the studies in literature (cont.).

Source	Data Collection Method	Musical Instrument Types Included in the Study	Information of the participants	Data Collected	Results & Conclusion
58-Victor *et al.* (2016)	• Questionnaire	Strings	934 musicians from Nigeria, age range: 17-45	Details of practice Playing related symptom occurrence and detail Stress related and not related with work Performance nervousness Personnel health evaluation	Insufficient warm-up, stress related and not related with work, and making music with more than one musical instrument were found related with risk of music related symptoms. Prevalence result found: 81.4% at whole body, 75.3% at wrists, 74.2% at neck, and 66.7% at lower back
59-Ackermann and Adams, (2004)	• Questionnaire	Strings	28 musicians and 7 health personnel	Subjective evaluations and rankings for the risks in musical instrument playing related discomfort and disorders	Inadequate posture, spending too much time for practice, short time of intervals between two practice sessions, and incorrect technique were stated as the important factors affecting instrument use related injuries.
60-Árnason *et al.* (2014)	• Questionnaire	Guitar Strings Vocal Plucked Strings Piano Percussion Woodwind Brass	74 musicians from 3 music schools	Instrument playing disorder occurrence and detail Time spent for practice (days in a week, number of times in a day, one practice session's duration) Precautionary education against playing related disorders	The music related musculoskeletal disorders were more frequent in students who were studying classical music than the students studying rhythmic music, moreover female students have much more injuries than male students. By participants, inadequate posture was stated to be the most important factor for music related injuries.
61-Ranelli *et al.* (2008)	• Questionnaire	Not stated	731 child musicians, age range 7-17	Symptom occurrence, location and intensity Physical activity Information of action being made by hands Handedness Class/term at school	Being female resulted in more music instrument playing related symptoms, and older students had more music related disorders. Prevalence result found: %56 at whole body

Table 2.3. Summary of the studies in literature (cont.).

Source	Data Collection Method	Musical Instrument Types Included in the Study	Information of the participants	Data Collected	Results & Conclusion
62-Oprea (2007)	• Video recordings analysis • Posture evaluation while playing	Strings Wind Percussion	75 musicians (49 men, 26 women; age mean 41.48)	Borg scale evaluation of the movements during holding and playing instrument, and giving a break Wrist movements Music related disorders detail	While playing a musical instrument, inadequate position of the upper limbs and overplaying might result in playing related musculoskeletal injuries.
63-López and Martínez, (2013)	• Questionnaire	Strings Plucked Strings Wind Brass Keyboard	166 music students (90 of whom took course related with music instrument related injury avoidance)	Years of playing The instrument played as main and second Practice detail (weekly) Detail of breaks during practice Symptom occurrence and location	There can be a reduction in the occurrence of the musical instrument playing related disorders by giving precautionary education to the musicians.
64-Kim *et al.* (2012)	• Questionnaire	Korean string instruments	86 professional musicians	Music related symptom location and severity Hobby detail Usage of cigarettes or alcohol	The music related disorders for two instrument types found to be positively correlated with height while the work and age factors are found correlated for an instrument type. Moreover, for an instrument type, hobby of the musicians is found correlated with the playing related disorders.
65-Sakai and Shimawaki (2010)	• Hand and finger dimension measurement by radiograph	Piano	220 injured pianists and 62 pianists with no injury	Little finger and thumb's abduction angles Hand span Thumb, little finger and middle finger's length	It was pointed out that the finger length and hand span were important factors affecting some type of music related injuries. Pianists that have smaller hands had more risk of music related injuries than the pianists with larger hands.

Table 2.3. Summary of the studies in literature (cont.).

Source	Data Collection Method	Musical Instrument Types Included in the Study	Information of the participants	Data Collected	Results & Conclusion
66-Russo *et al.* (2013)	• Questionnaire • Audiometry	Violin, Viola, Cello Woodwind Percussion Bass Brass	52 musicians from National Ballet of Canada Orchestra	Number of instruments played Years of playing Sound exposure which is not related with instrument playing Sound measurement	The hearing loss problems of the musicians were found to be related with instrument type. For ear protection, usage of earplugs is recommended, especially for the brass players.
67-Penzkofer *et al.* (2015)	• Audiometry • Questionnaire	Brass Wind	56 musicians from a wind orchestra	Occupation Hearing problem detail Subjective evaluation of personnel hearing problems Sound measurement	In every training session of the orchestra, sound level above 92 dB was detected. Musicians' hearing thresholds decreased after rehearsals. Musicians should use protective devices for ears in order to avoid hearing problems.
68- Pawlaczyk-Łuszczyńska, *et al.* (2011)	• Questionnaire • Sound Pressure Measurement	Strings Brass Wind Percussion Plucked Strings	127 musicians	Experience, education level Past injury or operation detail Weight, height Smoking status Subjective evaluation of hearing condition Hearing protector device usage Sound measurement	Musicians who were playing in the orchestra more than 40 years had more probability of having hearing loss problems. The instruments which had the risk of hearing loss problems were percussion, trumpet, tuba, and horn.
69-Pawlaczyk-Łuszczynska, *et al.* (2013)	• Questionnaire • Pure-tone audiometry • Transient-evoked otoacoustic emissions	Strings Brass Wind Percussion Plucked Strings	126 musicians (68 males, 58 females; age 24-67) from four symphony orchestras and two operas	Experience, education level Past injury or operation detail Weight, height Smoking status Subjective evaluation of hearing condition Hearing protector device usage Sound measurement	Females had lower risk of hearing loss when compared with male musicians, and young musicians had less probability of being affected by hearing loss than older musicians.

Table 2.3. Summary of the studies in literature (cont.).

Source	Data Collection Method	Musical Instrument Types Included in the Study	Information of the participants	Data Collected	Results & Conclusion
70- Gambichler *et al*. (2008)	• Questionnaire	Woodwind Brass Strings Plucked Strings Percussion Keyboard	412 musicians from nineteen German universities	Musical activity information Age, gender Skin irritations and their musical performance interference Experience	The skin symptoms were found related with time spent for practice in a week and the experience of the musicians. Musicians who were playing instruments from strings and plucked strings group were found to be in higher risk when compared with the musicians playing other instruments. Prevalence result found: 21.6% at their skin
71- Önder *et al.* (2000)	• Questionnaire	Not Stated	57 musicians from an orchestra (32 males, 25 females; age range 18-52 years)	Psychological factors such as stress, depression and nervousness	No strong correlation could be found between skin symptoms of musicians and psychological factors. It was pointed out that female musicians had more skin related problems than male musicians.
72-Steinmetz *et al.* (2014)	• Questionnaire	Strings Woodwind Brass Percussion Plucked Strings Keyboard	408 musicians (172 females, 236 males) from Berlin and Saxony-Anhalt classical orchestras	Age, gender Discomfort in the parts of the face in the last month Discomfort in face and other body parts in last 3 months Teeth grinding, jaw clenching habits The fear of performing on stage ranking	The fear of performing on stage and gender were found to be significant factors affecting instrument playing related discomfort in the face.
73- Rodríguez-Lozano and Bermejo-Fenoll (2010)	• Questionnaire • Clinical examination • Radiography results	Violin	41 musicians from Murchia (from two orchestras and a music school)	Age, gender Occupation Marial status Music related symptom detail Sounds from mouth joints Maximum mouth opening Abnormal oral habits	The musical instrument playing related symptoms were found related with abnormal oral habits, maximum mouth opening and sounds from mouth joints.

Table 2.3. Summary of the studies in literature (cont.).

Source	Data Collection Method	Musical Instrument Types Included in the Study	Information of the participants	Data Collected	Results & Conclusion
74-Eller, *et al*. (1992)	• Questionnaire • Direct interview • Blood pressure measurement • Lung function measurement • Rheumatological examination	Woodwind Strings Brass	91 musicians playing musical instruments and 51 opera singers from Denmark	Age, gender, occupation Average weekly playing Years of playing as a professional musician Blood pressure Height, weight Smoking habits Alcohol drinks consumed in a week	Musicians playing instrument had more discomfort in arms than singers, however, singers had more symptoms of throat, lips and mouth than the musicians playing musical instruments.
75- Ekşioğlu *et al*. (2014)	• Questionnaire	Drums	8 drummers having an age range of 20-30	Discomfort at all body parts	For drummers, the body position having the highest risk was found to be sitting while playing the instrument. The body parts drummers experiencing discomfort were lower back, neck, wrists and ankles. Recommendations related with playing position and musical instrument were given.
76- Cüceloğlu *et al*. (2009)	• Questionnaire	Flute	26 students playing flute having an age range of 18-21	Gender, age Graduated high school Years of flute education Discomfort detail at body parts	96.2% of the students had discomfort. Symptoms were mostly seen at the body parts of neck (53.8%), upper back (50%), lower back (34.6%), and lips (38.5%). It is stated that the main reason behind the discomfort was lack of warming up and stretching
77- Akel *et al*. (2010)	• Questionnaire • Posture evaluation • Video recordings	Flute	31 flute playing students studying music at universities	Different positions of flute holding and playing Demographics Discomfort detail at body parts	The discomfort at lips, jaws, right wrist and left pinkie were found to be different between the groups of different holding positions.

Table 2.3. Summary of the studies in literature (cont.).

Source	Data Collection Method	Musical Instrument Types Included in the Study	Information of the participants	Data Collected	Results & Conclusion
78- Ergin (2016)	• Questionnaire	Guitar	43 students playing guitar and studying music at a university	Knowledge about playing related discomfort and the muscles of the body Guitar playing habits and practice time Discomfort detail	Symptoms were found at elbows (51%), wrists (44%), and fingers (53%)

2.3.2. Common and Conflicting Findings of the Studies About the Factors Affecting Musical Instrument Playing Related Symptoms and Injuries

According to the results of the studies, there are various factors affecting musical instrument playing related disorders. Some of the factors were found related with the playing related disorders in some studies while the same factors were stated not to have a direct effect in other studies. The factors investigated are explained below.

2.3.2.1. Age. Age was found as one of the important factors affecting playing related disorders (Furuya *et al.*, 2006; Ranelli *et al.*, 2011; Sandell *et al.*, 2009; Ranelli *et al.*, 2008; Kim *et al.*, 2012; Pawlaczyk-Łuszczynska *et al.*, 2013). However, the studies made by Victor *et al.* (2016) and Gambichler *et al.* (2008) showed that there is no relation between age and playing related injuries. Ranelli *et al.* (2008) expressed that older children have more probability of having musculoskeletal disorders or symptoms and Pawlaczyk-Łuszczynska *et al.* (2013) stated that young musicians have less probability of being affected by hearing loss than older musicians. Nevertheless, Sandell *et al.* (2009) stated that probability of injuries decreases with increasing age.

2.3.2.2. Gender. Gender was also found to have an effect on the instrument playing related discomfort (Ranelli *et al.*; Paarup *et al.*, 2011; Altenmüller *et al.*, 2012; Barton *et al.*, 2008). As stated by Brusky (2010), Rickert *et al.* (2012), Zaza and Farewell (1997), Fjellman-Wiklund and Edling (2009), Árnason *et al.* (2014), Ranelli *et al.* (2008), female musicians have more risk of playing related discomfort than male musicians. However, Altenmüller *et al.* (2012) found out that male musicians have higher risks of instrument playing related injuries and Pawlaczyk-Łuszczynska *et al.* (2013) pointed out that female musicians had lower risk of hearing loss when compared with male musicians. These studies showed that gender is an essential factor affecting musical instruments playing disorders, nevertheless, in the study made by Gambichler *et al.* (2008) about the skin problems of the musicians, any significant correlation couldn't be found between gender and playing related symptoms or injuries.

2.3.2.3. Instrument Type. Instrument type was one of the most important contributing factors for instrument playing related injuries (Ranelli *et al.*, 2011; Barton *et al.*, 2008;

Kim *et al.*, 2012; Russo *et al.*, 2013; Pawlaczyk-Łuszczyńska *et al.*, 2011). León *et al.* (2015) expressed that the location of the injuries was affected by the type of the instrument. In the studies made, the instruments having the highest risk of playing related discomfort or injuries were pointed out and the instruments were compared with each other for risks of playing related problems. Steinmetz *et al.* (2010) stated that string players had more postural stabilization system impairments than keyboard and symmetrically played wind instrument players. Furthermore, Zaza and Farewell (1997) found out that string players had more risks of being injured. What's more, according to the study made by Gambichler *et al.* (2008), musicians who are playing instruments from strings and plucked strings group were found to be in higher risk when compared with the musicians playing other instruments. However, Altenmüller *et al.* (2012) expressed that brass, guitar and woodwind players have more risks of musculoskeletal symptoms than the other musicians. Nevertheless, according to the study made by Paarup *et al.* (2011), woodwind players were found to have less probability of having musical instrument playing related injuries. In the study made by Sandell *et al.* (2009) with percussionists, the keyboard percussionists were found out to have the highest prevelance of music related injuries among all type of percussionists.

2.3.2.4. Awkward Posture and Body Position. Another essential element affecting musculoskeletal disorders of the musicians was inadequate posture (León, *et al.*, 2015; Mishra and Gangopadhyay, 2013; Ackermann and Adams, 2004; Árnason *et al.*, 2014). Moreover, Steinmetz *et al.* (2010) stated that postural stabilization problem had an effect on playing related disorders. Furthermore, playing position was found to be associated with playing related injuries (Nyman *et al.*, 2007; Fjellman-Wiklund and Edling, 2009). As stated by Blanco-Pineiro and Diaz-Pereira (2015) students who are in a seating position while playing had more risk of having incorrect postures than standing students.

2.3.2.5. Playing Technique. One of the factors which was found to be associated with musical instrument playing disorders was the playing technique (Fry, 1987; León *et al.*, 2015; Ackermann and Adams, 2004). Therefore, it would be better for musicians to play their instruments with the correct technique in order to avoid playing related injuries.

2.3.2.6. Training Length, Breaks, Practice Intensity and Time Spent for Practice. Training length was stated to be associated with playing related disorders (Knapik, *et al.*, 2007; Ackermann and Adams, 2004). Linari-Melfi *et al.* (2011) and Furuya *et al.* (2006) stated that instrument playing related disorders increased when the daily practice time increased. Moreover, Kaufman-Cohen and Ratzon (2011), Gohil *et al.* (2016), and Gambichler *et al.* (2008) stated that weekly playing hours affected instrument playing related disorders. What's more, Gohil *et al.* (2016) expressed that monthly spent time for instrument playing had an effect on musculoskeletal disorders of musicians. However, any correlation couldn't be found with instrument playing related injuries and training length in some studies (De Smet *et al.*, 1998; Victor *et al.*, 2016). In addition, Fjellman-Wiklund and Edling (2009) stated that there was no association between weekly playing hours and musical instrument playing related disorders.

Besides training length and time spent for practice, breaks and practice intensity play an important role in musculoskeletal disorders of musicians. In the study made by Ackermann and Adams (2004), breaks between practice were stated to have an important effect on playing related injuries. Moreover, Fry (1987) expressed duration and intensity of practice affects playing related disorders. Furthermore, Chan, *et al.* (2000) found out that discomfort of the whole body was found to be different before and after a training session. Oprea (2007) stated that over-playing affects instrument playing related injuries, thus, if there is a chance, the intensity of the practice should be well adjusted in order to avoid musculoskeletal disorders.

2.3.2.7. Warming-up. Another important factor which has an essential effect on instrument playing related injuries is warming-up. Victor *et al.*, (2016) found a relation between warming-up and playing related injuries while De Smet, Ghyselen, and Lysens (1998) didn't find any association.

2.3.2.8. Years of playing and experience. If a musician is actively playing his or her instruments for a long time, the experience of the musician is increased. Zaza and Farewell (1997) found out that the years of playing was associated with musical instrument playing related disorders and Pawlaczyk-Łuszczyńska *et al.* (2011) stated that years of playing in orchestra affects playing related injuries. Moreover, Gambichler *et al.* (2008) pointed out

experience had an effect on music related disorders. Nevertheless, Victor *et al.* (2016) didn't find any relation between years of playing and disorders, and De Smet *et al.* (1998) couldn't find any correlation between age of start to play and playing related injuries.

2.3.2.9. Past Injuries. As stated by Knapik *et al.* (2007) and Dommerholt (2009c) past injuries affects musical instrument playing disorders.

2.3.2.10. Hypermobility. Hypermobility was stated to be related with playing related symptoms or injuries. (Zaza and Farewell, 1997; Larsson *et al.*, 1993; Dommerholt, 2009c)

2.3.2.11. Physical Activeness. Musicians having a low level of physical activeness were found to have higher risks for musical instrument playing related injuries (Nawrocka *et al.*, 2014; Knapik *et al.*, 2007). However, De Smet *et al.* (1998) couldn't find any association between disorders of the musicians and being physically active.

2.3.2.12. Hand Size, Hand Span and Finger Length. Hand span was found to have an effect on the risk of musicians' injures (Lai *et al.*, 2015; Sakai *et al.*, 2006). Smaller hands were pointed out to result in more risk of instrument playing related injuries (De Smet *et al.*, 1998). Linari-Melfi *et al.* (2011) found out that pianists who have neck pain had smaller hands than the pianists who don't have neck pain. Moreover, Sakai and Shimawaki (2010) stated that smaller hands resulted in higher risks of injury for pianists and they further stated that finger length was also associated with playing related injuries. The studies showed that size of the hand, fingers and hand span had an effect on musicians' injuries, however, in the study made by Furuya *et al.* (2006), hand size wasn't found as a contributing factor to musical instrument playing disorders.

2.3.2.13. Playing more than One Instrument. Victor *et al.* (2016) stated that if the number of instruments played was larger than one, musicians had higher risk of playing related injuries. However, De Smet *et al.* (1998) didn't find any relation between number of instruments played and musculoskeletal disorders of the musicians.

2.3.2.14. Stress and Nervousness. Being anxious in daily life was stated to increase the risk of musicians' injuries (Furuya *et al.*, 2006). What's more, nervousness in daily life was

pointed out to be an important factor on playing related disorders (Zaza and Farewell, 1997). Furthermore, stress was found to be correlated with instrument playing related injuries (Rickert *et al.*, 2013; Sandell *et al.*, 2009; Victor *et al.* 2016) while Önder *et al.* (2000) couldn't find any effect of stress on skin disorders of the musicians. Moreover, Steinmetz *et al.* (2014) stated that fear of performing on stage affected symptoms on musicians' faces.

2.3.2.15. Positive approach to practice. Furuya *et al.* (2006) stated that positive approach to practice increased the risk of playing related injuries.

2.3.2.16. Body-Mass Index and Height. Body-mass index was found to be associated with playing related injuries (Zaza and Farewell, 1997). Moreover, as stated by Knapik *et al.* (2007), high body-mass index resulted in higher probability of music related disorders. What's more, Kim *et al.* (2012) expressed that height of the musician had an effect on musculoskeletal disorders of musicians.

2.3.2.17. Instrument Weight. Kaufman-Cohen and Ratzon (2011) stated that instrument weight was an important factor for the disorders of musicians.

2.3.2.18. Genetic Factors. Fry (1987) stated that the risk of musicians' disorders was affected by being sensitive genetically.

2.3.2.19. Trigger point discomfort. Rickert *et al.* (2012) stated that trigger point discomfort was related with musicians' injuries.

2.3.2.20. Being Open-Minded and Sentimentally Stable. In the study made by Levy *et al.* (2009) being open-minded and sentimentally stable were found related with playing related injury risk.

2.3.2.21. Somatizing Disorder. Leaver *et al.* (2011) stated that somatizing disorder increased the playing related injury risk for musicians.

2.3.2.22. Type of Music Studies. According to the study made by Árnason *et al.* (2014), type of music studies affects instrument playing related disorders.

2.3.2.23. Precautionary Education Against Playing Related Disorders. In the study made by López and Martínez (2013) it was expressed that giving precautionary education may reduce the playing related injuries.

2.3.2.24. Occupation. Kim *et al.* (2012) stated that occupation is related with playing related injuries. Moreover, as it was expressed in the studies that musicians have more musculoskeletal problems than non-musicians (Kok *et al.*, 2013; Kok *et al.*, 2013a). Furthermore, Plevnik, Bazon, and Pisot (2015) stated that the importance of the music related injuries was better known by the music teachers than the music students.

2.3.2.25. Hobby. Kim *et al.* (2012) found out that the hobbies of the musicians affected playing related disorders of the musicians.

2.3.2.26. Abnormal Oral Habits, Maximum Mouth Opening, and Sounds from Mouth Joints. In the study made by Rodríguez-Lozano and Bermejo-Fenoll (2010), it was found out that abnormal oral habits, maximum mouth opening and sounds from mouth joints affected musical instrument playing related symptoms at face.

2.3.2.27. Left and Right Upper Extremity RULA Score Difference. Kaufman-Cohen and Ratzon (2011) showed that there was a relation between left and right upper extremity RULA score difference and musical instrument playing related injuries.

2.4. Critics of findings

The results of the studies indicate that there were conflicting findings about some factors affecting playing related disorders of the musicians. For instance, it was stated by some studies that the risk of the instrument playing related musculoskeletal disorders increase at higher ages, while other studies express that young musicians are at higher risk. What's more, some studies stated that the females have more risk of playing related

injuries while other state that males have much more risk. Also, according to some studies, playing a type of instrument was expressed to be risky for playing related musculoskeletal disorders while for the other studies that instrument type was not risky as the other instrument types.

The studies made for music related musculoskeletal injuries in the literature are generally not comprehensive. Some of the researches only focuses on a specific instrument. Even though the studies made for only one instrument state essential results, they cannot be used to make a general comparison of musculoskeletal symptoms or injuries between the instrument groups. The risks or the prevalence between the music groups cannot be evaluated.

In some researches data were only collected from a specific group such as a music school or a region. In some studies, data were collected from some clinics where musicians were receiving treatment, which makes the data area-specific. In order to make a general research for the music related musculoskeletal injuries or symptoms, subjects from different places should be analyzed so that the factors depending on the location can be evaluated.

Some studies were made with sample size less than 10 people. In order to draw conclusions, more participants could be involved in the studies. The prevalence of the musculoskeletal injuries or symptoms can be better understood if the sample used is higher.

There were studies giving advice to healthcare professionals to understand the musicians' needs and design treatments accordingly. In order to increase the efficiency of the treatments, the data from the surveyed groups could be used in order to determine the body areas affected for each instrument group. Therefore, an instrument specific treatment program could be determined as a result of the studies. Moreover, the treatments could be designed according to the musicians' gender, age group, hand size and other factors. To specify the treatment requirements, the data from the survey could be used.

Furthermore, according to the studies' results, one of the main causes of the playing related injuries, which is the improper instrument design, was not mentioned. There is no doubt that the musical instruments' main aim of design is to produce the best sound. However, in order to design instruments for human requirements, ergonomic factors should be involved. There are plenty of factors of the instrument use related musculoskeletal symptoms, however, making a new instrument design or improving the current musical instrument design may help to avoid injuries. The opinion of the musicians could be collected and design suggestions could be made accordingly. Moreover, for the usage of musical instruments, the awareness of the instrument ergonomics could be evaluated by collecting musical instrument preferences from musicians. The preference of the musicians could be used in order to evaluate how much importance does the ergonomic factors have from the musician point of view.

3. RATIONALE AND OBJECTIVES OF THE STUDY

3.1. Rationale of the Study

As the literature review shows, MSDs are widespread among musicians. There are some studies which investigated all instrument groups by considering age, gender, instrument type effects on MSDs, however, only a few studies included all instrument groups, and the data were collected from same age group, same bands or orchestras or the sample size was low. For instance, Knapik *et al.* (2007) collected data from 205 army band members, Plevnik, *et al*. (2015) collected data from 43 music students, and Kok *et al.* (2013) only collected information from students. Ioannou and Altenmüller (2014) made a study with low sample size of 83 musicians, and Altenmüller *et al.* (2012) investigated the patient files without directly applying questionnaire to the musicians. Chan *et al*. (2013) made triage sessions with 84 professional musicians, and Árnason *et al*. (2014) only investigated musicians from schools. Gambichler *et al.* (2008) only considered the skin symptoms of musicians as an output and Steinmetz *et al*. (2014) only collected data from orchestras which might restrict the age range of the data. This study covered a wider age range of the participants from each musical instrument group in order to investigate the musculoskeletal symptoms during instrument playing.

There is only single study made by Ranelli *et al.* (2011) which considered the effect of musical instrument playing related symptoms on musical performance, and that study was on children. This study investigated the musical performance interference at each body part for a wider musical instrument and age range of participants.

Moreover, there is no study that identified the risk levels for all instrument groups by using a sophisticated ergonomic evaluation tool such as RULA except Kaufman-Cohen and Ratzon (2011). However, their study only considered the instrument groups of strings and wind, thus, a comparison between the musical instrument groups by using RULA will clarify and compare the playing related symptom risks of each instrument group.

None of the studies looked at the association between hand dimensions and the discomfort for all instrument groups. By the survey tool developed, the details of the symptoms at hand parts such as bottom of thumbs, fingers and hand palms will be collected and the relation between hand dimensions and these symptoms will be evaluated.

Last but not least, in Turkey, the studies made so far by Cüceloğlu *et al*. (2009), Akel *et al*. (2010) and Ergin (2016) only considered an instrument group such as flute or guitar, thus, this study will be the first comprehensive study to analyze musical instrument playing related discomfort in Turkey.

3.2. Objectives of the study

Based on the rationale above, the objectives of the study are defined as follows:

(i) Estimating the prevalence and the musical performance interference of the playing related symptoms among musicians;
(ii) Investigating the musical performance interference effects of MSD symptoms;
(iii) Investigating the effects of gender, experience, instrument type and other factors on MSD symptoms and performance interference;
(iv) Investigating the association between hand dimensions and MSD symptoms;
(v) Evaluating the MSD risk of each instrument group;
(vi) Developing recommendations for each instrument group.

4. METHODOLOGY

4.1. Phases of the Study

The phases of the study are illustrated in Figure 4.1.

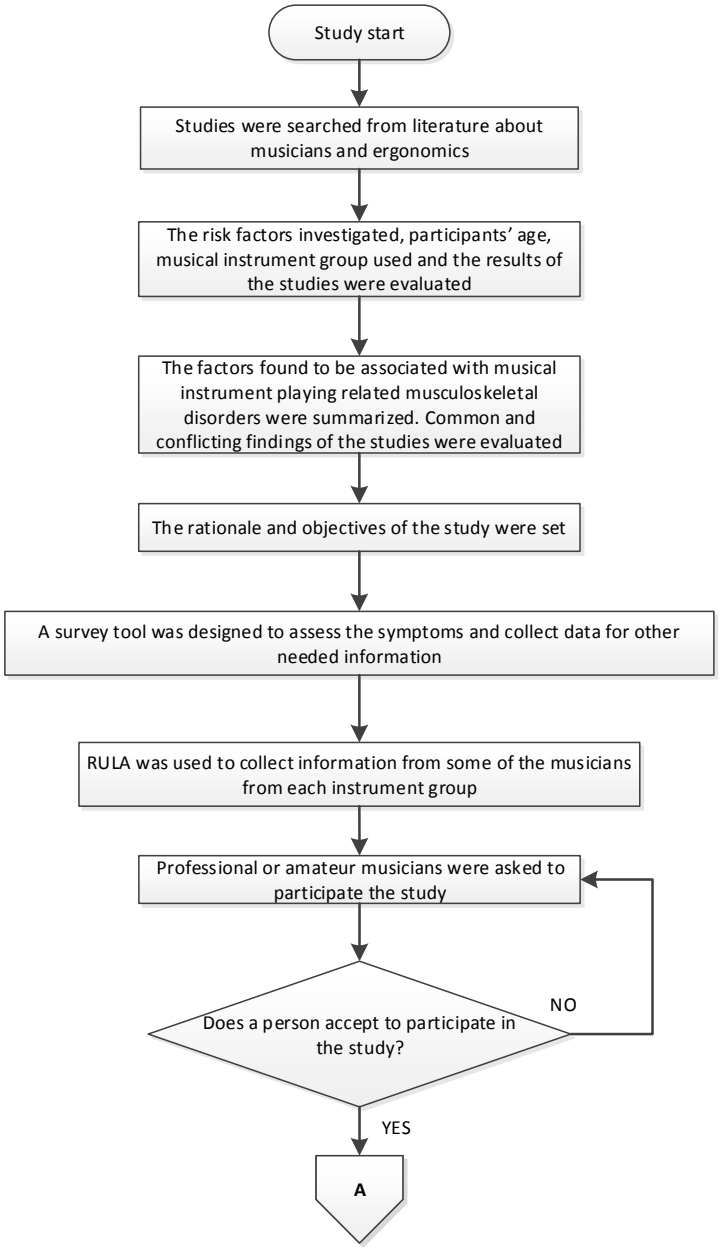


Figure 4.1. The phases of the study

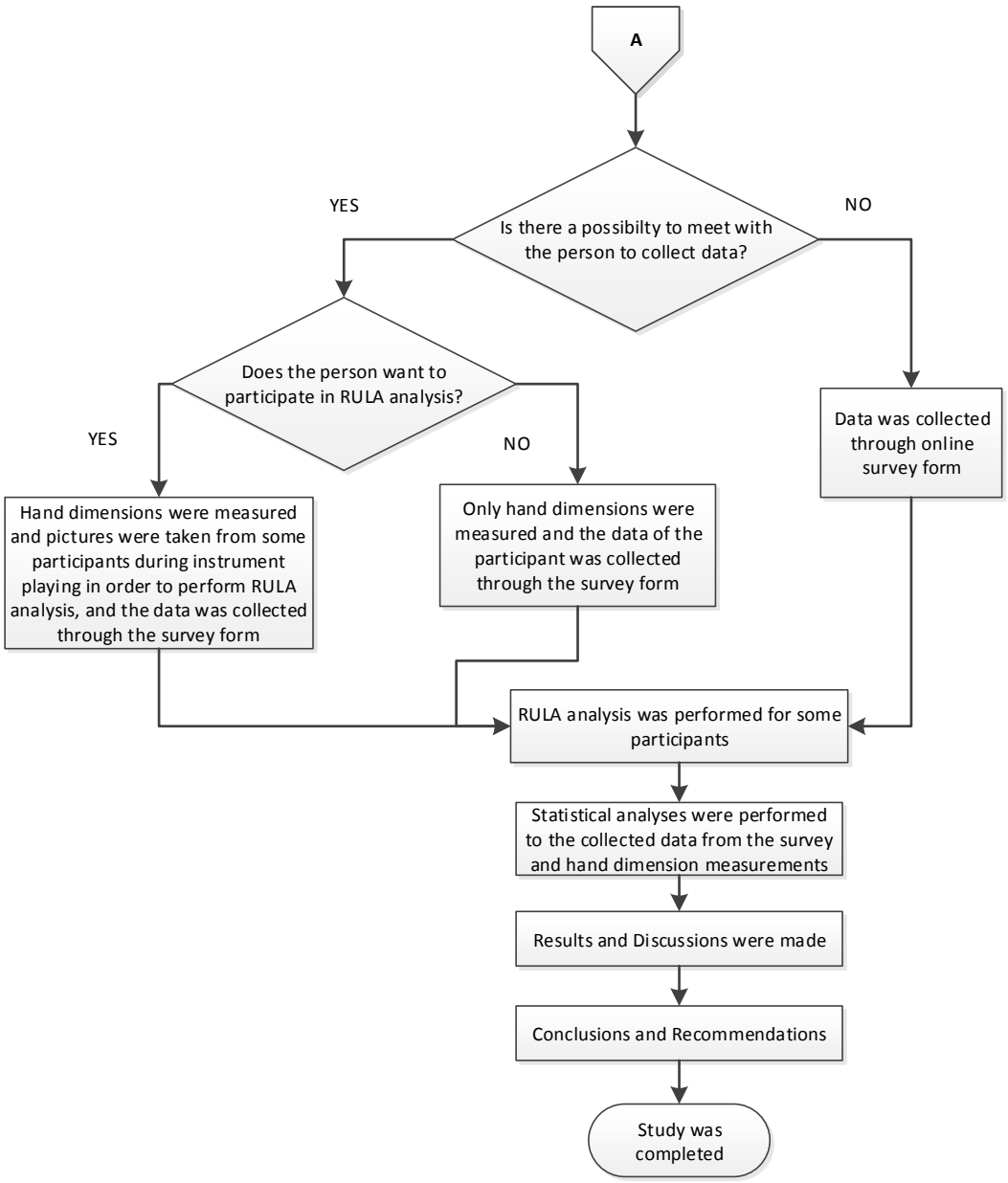


Figure 4.1. The phases of the study (cont.).

4.2. Tools and Equipment

In order to collect data from the participants, a specifically designed survey, a caliper for hand measurement, and a camera to take photographs of the musicians during playing of a musical instrument were used. The details of the tools used are explained below.

4.2.1. Survey Tool

By using the survey designed for the purpose of this study, participants' data related with their physical attributes, daily life, musical instrument usage, musical instrument playing related symptoms and preferences or ideas about musical instrument design were collected. The survey was designed based on the Student-Specific Cornell Musculoskeletal Questionnaire (Ekşioğlu, 2017) and it was adapted to collect information from musicians. The survey form is shown in Appendix A and the details are provided below.

4.2.1.1. Part-1. The survey's first part consists of questions in order to collect general information from participants. The age, gender, height and weight of the subjects were asked. This information was used to investigate whether age, gender and body-mass index (BMI) have an effect on the musical instrument playing related symptoms. BMI was calculated by using the Equation (4.1).

$$BMI = \frac{weight(kg)}{height^2(m^2)} \tag{4.1}$$

Moreover, the city of family origin, hand dominance and occupation of the participants were asked. The participants' occupations were categorized if they were related with music or not and the effect of them was investigated. The city of family origin and hand dominance were collected in order to obtain general information about the participants.

In order to evaluate health of the subjects, the questions related with smoking and alcohol usage were asked. If a participant was smoking, it was asked how many packages of cigarettes per day are consumed. Moreover, if a participant was drinking alcohol, the number of times in a week was asked. Furthermore, the information of average hours of daily sleep was asked since sleeping is a critical factor for the human health. What's more, the participants were asked if they regularly exercise including walking each week, due to the sports' effect on human body health. However, from the health-affecting factors described below, only average hours of sleep and making regular exercise were included in the inferential analysis in order to reduce the number of factors investigated.

For the collection of the data related with musical instrument usage, the main and second instruments played and average playing hours spent in a week for each instrument were asked. Also, in order to understand the musicians' experience level, the years of playing information for both instruments were requested. Since musicians often play more than one musical instrument, the details related with main and second instrument usage were asked in the survey. For instance, a musician playing the piano as the main instrument can also spent some of his or her time playing guitar to make recordings etc. or during live performance. Moreover, for another example, during music education in conservatory, most of the music students take piano courses besides their first instruments (e.g. violin, flute etc.). Thus, the information from main and second instruments were gathered for these reasons and it was investigated whether playing more than one instrument has an effect on playing related symptoms. The collected instrument data were analyzed by separating the instruments to the six main instrument groups which are strings, keyboard, plucked strings, woodwind, drums and percussion, and brass. The instrument groups and corresponding instruments are shown in Figure 4.2.

Figure 4.2. Instrument groups

Furthermore, participants were asked how much their practice sessions last and how much time they give a break between two practice sessions. This is essential because if a musician practice too much, it might result in overexertion of the muscles. Moreover, the time for rest breaks are important because while playing a musical instrument, muscle fatigue can occur and the strain affecting them needs to be stopped for sufficient amount of time in order to avoid injuries. What's more, warming up is essential as well as the time spent for practice and breaks since it makes human body prepared for the musical instrument playing, like warming up before a sports activity. Thus, musicians were asked if they warm up before practicing. Also, the music type played information was requested and the participants were asked whether they received an injury preventive education. However, the music type played and the injury preventive education information was not used for inferential statistics in order to reduce the factors investigated.

Previous injury might affect musical instrument playing related symptoms, so the participants were asked if they had any previous musculoskeletal injury or not. In case of any previous injury, the details of the injury and the injury's music relatedness were asked. It was further requested from the participants to state the cause and possible precautions to avoid the music related injuries they had. The participants were excluded from the survey if their previous injury were not related with music and the injury's location was at the body part that the musician was experiencing symptoms. The survey further requested the information of the discomfort detail if the participants had symptoms during musical instrument playing.

Since stress affects the health of a person, it was investigated as a factor contributing to the musical instrument playing related discomfort and in the survey participants were asked to state their stress level during their daily life and during a musical performance on a five-level Likert Scale (Likert, 1932).

People are using technological devices every day for completing their tasks at work, staying connected with friends through social platforms on the internet, searching for new information, shopping or for other purposes. Therefore, daily usage of the computers and the cell phones might have an effect on the musical instrument playing related symptoms since the hands are the mostly used body parts during the interaction with a computer or a

cell phone, also the people might have inadequate body posture while using them. Thus, the number of hours spent for computer and cell phone usage per day was asked, and for the hours of cell phone usage information, the time spent only for text messaging, surfing the internet, or social media usage was requested because only in these events the hands and fingers are more actively used than talking on the phone.

Lastly, two questions were asked to the participants in order to collect their suggestions about more comfortable instrument playing. The first question requested a general feedback about the factors for musical performance improvement, to illustrate, method related changes, time related adjustments and design changes for the musical instruments. In the second question, participants were asked to express their design change ideas for their main instrument played in order to have higher level of comfort and performance.

4.2.1.2. Part-2. The second part of the survey consists of a diagram showing the body parts and the participants were asked to mark the appropriate boxes that best describes the discomfort in terms of frequency, severity and musical performance interference during the last week of instrument playing. This part was adapted from Student-Specific Cornell Musculoskeletal Questionnaire (Ekşioğlu, 2017) and was modified according to the musicians' symptom collection. Since musicians might have hearing problems, the ears were added to the body parts for data collection. Moreover, in order to collect the problems of the musicians playing wind or brass instruments, face/jaws, mouth/lips were added to the questionnaire. However, since the visual discomfort is considered to be more affected from other factors (e.g. computer usage reading, etc.) than musical instrument playing, eyes were removed from the questionnaire. The academic performance interference in the original questionnaire was changed to musical performance interference in order to investigate whether the discomfort experienced by musicians have an effect on their performance.

In the frequency part of the symptom collection, the participants were requested to state the frequency of their discomfort during the last week of instrument playing and were asked to state whether if it occurs 1-2 times, 3-4 times, once every day or several times in a day. If the participants don't feel any discomfort with the related body part, they were

requested to mark ‘never’. If a discomfort is experienced, the participants were asked to state the severity level to be slightly, moderately, or very uncomfortable. Also, the participants were requested to state the level of musical performance interference of their discomfort. They were requested to mark the interference level as ‘not at all’, ‘slightly interfered’ or ‘substantially interfered’.

The weighted score of the body parts were calculated as in the study made by Ekşioğlu (2017). The weighted score of a body part were calculated from multiplication of the weights of frequency, severity and performance, which is also shown in Equation (4.2). The weighted score of a body part can have a value of minimum 0 and maximum 90. The weights given for each of the frequency, severity and musical performance interference parts are as illustrated in Table 4.1.

$$WS_i = F_i \times S_i \times MPI_i$$
$$i = 1,2\ldots 40 \ (i\text{:body part}) \tag{4.2}$$

In Equation (4.2), WS_i is the weighted score at each body part and F_i, S_i, MPI_i are the frequency, severity, and musical performance interference at each body parts, respectively. After the weighted scores of all the body parts of the participants were calculated, the body parts were ordered from the largest weighted score to smallest weighed score and the first five body parts having the large weighted scores were taken into consideration for further analyses.

Table 4.1. The weights of frequency, severity and musical performance interference

Part	Symptom Detail	Weight
Frequency	Never	0
	1-2 times in a week	1.5
	3-4 times in a week	3.5
	Once every day	5
	Several times every day	10
Severity	Slightly uncomfortable	1
	Moderately uncomfortable	2
	Very uncomfortable	3
Musical Performance Interference	Not at all	1
	Slightly interfered	2
	Substantially interfered	3

4.2.1.3. Part-3. The data collection method of the third part of the survey is basically the same as Part-2, however, in this section the hand parts were added to the original questionnaire. For both hands, the discomfort occurring at thumb, index finger, middle finger, ring finger, pinkie, palm and bottom of thumb of the participants were collected. Again, the frequency, severity and musical performance interference were asked and the calculation method of the weighted scores of all hand parts are the same as Part-2.

From the symptom data collected from both Part-2 and Part-3, the total body weighted score (TBWS) of the discomfort for a subject were calculated by summing up the weighted score values of 40 body parts (WS_i), which is explained in Equation (4.3). The total body weighted score can have a minimum value of 0 and maximum value of 3600.

$$TBWS = \sum_{n=1}^{40} WS_i \qquad (4.3)$$

i =1,2….40 (i:body part)

Besides the calculation of the weighted scores, the prevalence and the musical performance interference ratios were also calculated for further analysis. For the calculation of the prevalence and the performance interference ratios, the prevalence and musical performance interference binary operators of each body part were calculated as shown in Equations (4.4) and (4.5),

$$PB_i = \begin{cases} 0, & if\ F_i = 0 \\ 1, & else \end{cases} \qquad (4.4)$$

i =1,2….40 (i:body part)

$$MPIB_i = \begin{cases} 0, & if\ F_i = 0\ or\ F_i \neq 0\ and\ MPI_i = 1 \\ 1, & else \end{cases} \qquad (4.5)$$

i =1,2….40 (i:body part)

where PB_i and MPB_i are the prevalance and musical performance interference binary operators for ith body part, F_i is the frequency of ith body part, MPI_i is the musical

performance interference score for the i[th] body part, in reference to Musicians' symptom survey and Table 4.1.

After these binary operators for each subjects' i[th] body part were calculated, the prevalence and musical performance interference ratio for each body part were calculated from the equations (4.6) and (4.7), respectively.

$$PR_i(\%) = \frac{n_{PB_i=1}}{n_t} \times 100 \tag{4.6}$$

$$MPIR_i(\%) = \frac{n_{MPIB_i=1}}{n_t} \times 100 \tag{4.7}$$

The PR_i and $MPIR_i$ stand for prevalance and musical performance interference ratio at i[th] body part respectively in the Equations (4.6) and (4.7), $n_{PB_i=1}$ and $n_{MPIB_i=1}$ are the numbers of participants having symptoms and musical performance interference at i[th] body part, respectively, and n_t is the total number of participants.

The total body prevalence and total body musical performance interference values were calculated from the equations (4.8) and (4.9) respectively,

$$TBP = \begin{cases} 0, & if \sum_{i=1}^{40} PB_i = 0 \\ 1, & else \end{cases} \tag{4.8}$$

$$TBMPI = \begin{cases} 0, & if \sum_{i=1}^{40} MPIB_i = 0 \\ 1, & else \end{cases} \tag{4.9}$$

where TBP and $TBMPI$ are the total body prevalance and total body musical performance interference taking binary values of 0 or 1.

The total body prevalence and total body performance interference ratios were calculated by using the equations (4.10) and (4.11) respectively,

$$TBPR(\%) = \frac{n_{TBP=1}}{n_t} \times 100 \tag{4.10}$$

$$TBMPIR(\%) = \frac{n_{TBMPI=1}}{n_t} \times 100 \tag{4.11}$$

where $TBPR$ is the total body prevalance ratio, and $TBMPIR$ is the total body performance interference ratio, $n_{TBP=1}$ and $n_{TBMPI=1}$ are the number of participants having total body prevalance and total body musical performance interference values of 1 respectively, n_t is the total number of participants. In all calculations above except Equations (4.1), (4.2), (4.3), we only considered whether a symptom or interference exists or not. That is, we didn't consider the frequency level or interference level of performance.

4.2.2. Hand Measurement

In order to investigate the hand dimensions' effect on the musical instrument playing related disorders, some participants' hand dimensions were measured. In order to measure hand dimensions, a caliper was used. (Figure 4.3.)

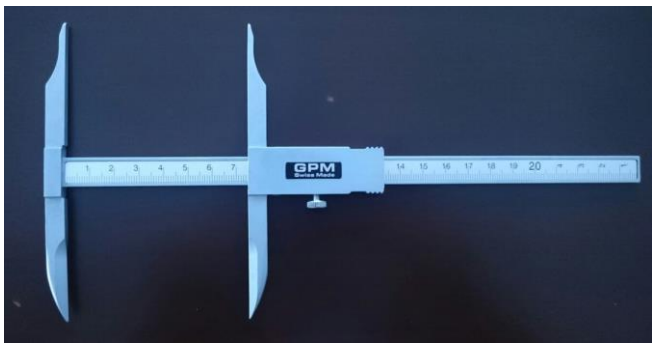
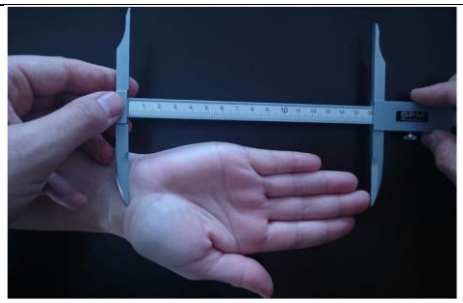
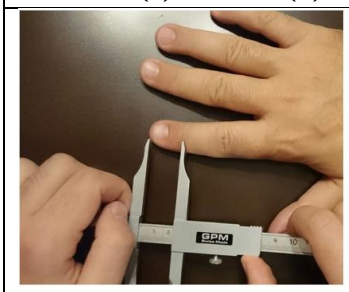
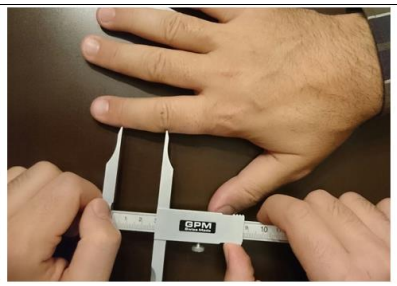
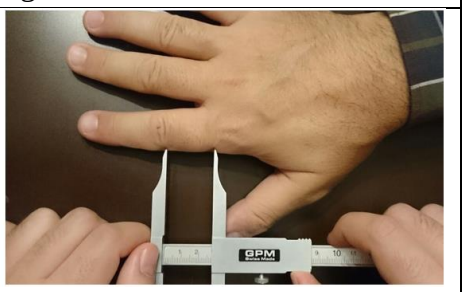
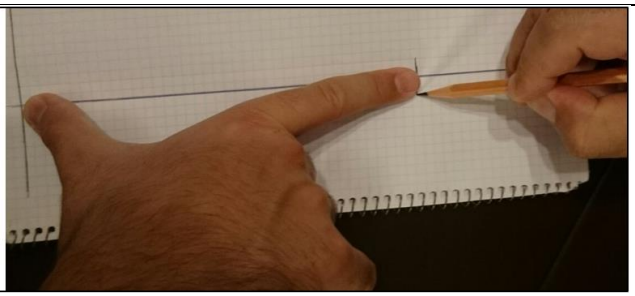


Figure 4.3. Caliper

Participants' hand lengths and breadths were measured as shown Table 4.2. Moreover, lengths and the widths of the fingers of the participants were measured by using the caliper. The lengths of distal, middle and proximal parts were measured for all the fingers. The width of all the fingers were measured as well. The measurement method of the length and width of the fingers is illustrated in Table 4.2.

Table 4.2. Hand measurement methods

Hand Measurement Methods
1- Hand length (a) and breadth (b) measurement
  (a) (b)
2- Distal (a), middle (b), and proximal (c) length of the fingers measurement
   (a) (b) (c)
3- Finger width measurement

4- Hand span (a) and the thumb and index finger span (b) measurement
  (a) (b)

Furthermore, left and right hand spans were measured. Hand size and hand span are important for playing some instruments, for instance, pianists with larger hands can easily play octaves or chords, thus, the hand span and the span of thumb and index finger were

collected. The effect of the hand spans of the participants on the musical instrument playing related disorders will be investigated. The measurement method of the hand span and the span of thumb and index finger is illustrated in Table 4.2. Firstly, the participants were requested to place their thumb of one hand onto a point which is specified and marked before. After that, without removing their thumb from the marked point, participants were requested to stretch their hands as much as possible and touch the furthest point on the line. This procedure was applied for measuring the span of the thumb and the index finger as well. Participants were requested to stretch their hand and place their index finger onto the furthest point on the line without removing their thumb from the marked point. The measurement process was then repeated for the other hand.

4.2.3. RULA (Rapid Upper Limb Assessment) Tool

Rapid Upper Limb Assessment (RULA) was used in determining the playing related risk levels by observing and evaluating posture during playing (Appendix C). RULA is a tool developed by McAtamney and Corlett (1993) in order to perform risk analysis for the tasks in which the upper limbs are mostly used. It is a widely used tool for job risk evaluation.

RULA consists of evaluations for every part of the upper limbs of a person. When applying RULA, the points from two main sections, one of which is arm and wrist analysis and the other one is neck, trunk and leg analysis, are used to calculate the final score. The arm and wrist analysis section consists of the evaluation of the upper arm, lower arm and wrist of a subject. After the effect of force or load and muscle usage is added, the total score of arm and wrist is calculated. The other section of RULA consists of neck, trunk and leg score evaluation. Similar to the previous section, the load or force effect with the muscle usage effect is added to calculate the total score of the neck, trunk and leg analysis section. The total scores of these two sections are later used to calculate the final RULA score of the subject evaluated (McAtamney and Corlett, 1993).

One or two instruments from each musical instrument family were selected for evaluation. Since both arms or hands might not perform symmetrical movements during instrument playing, the left and right upper limbs were evaluated separately. For the

symmetric musical instrument playing positions of the upper limbs, RULA was applied for both upper limbs together. The RULA form used was taken from the website of Ergonomics-Plus (Ergonomics Plus, n.d.).

4.3. Statistical Analysis

In order to perform statistical analysis, the statistical softwares Minitab 17.3 and R were used. Minitab was used for obtaining descriptive statistics and performing ANOVA. R software was used in order to perform Logistic regression, and to calculate the area under the curve (AUC) for the logistic regression models. In all the statistical analyses applied, the p-value ≤ 0.05 was accepted as significant. The details of the statistical analysis methods used in the study are explained below.

4.3.1. Descriptive Statistics

The mean, standard deviation, minimum and maximum values of the continuous variables were calculated as descriptive statistics and the number and percentage of the participants corresponding to categorical factors were shown. The descriptive statistics were calculated separately for females and males.

4.3.2. Correlation Analysis

The Spearman's rank order correlation coefficient was used in the study in order to calculate the correlation between the hand dimensions and weighted scores, also for investigating the multicollinearity between the continuous and ordinal variables. Besides the correlation coefficients, p-values were calculated as well to check if there exists a significant correlation. The reason for using Spearman's correlation coefficient is that the weighted scores had outlier values and it was going to affect the linear relationship which was going to be calculated by Pearson correlation coefficient, and usage of Spearman's correlation coefficient would be more appropriate in this case. Moreover, Spearman's correlation coefficient is better for calculation of the correlation coefficients when there are ordinal variables. The Pearson and Spearman's correlation coefficients' details and their difference are explained below.

4.3.2.1. Pearson Correlation Coefficient. The Pearson correlation coefficient, also called as Pearson product-moment correlation coefficient, can be calculated from the Equation (4.12),

$$r_p = \frac{cov(X,Y)}{\sigma_X . \sigma_Y} \tag{4.12}$$

where r_p shows the Pearson correlation coefficient, $cov(X,Y)$ shows the covariance of the variables X and Y, σ_X and σ_Y shows the standard deviations of X and Y respectively. The Pearson correlation coefficient shows the linear relationship power of X and Y (Sarabia *et al.* 2008).

4.3.2.2. Spearman's Correlation Coefficient. Spearman's correlation coefficient, also called as Spearman's rank-order correlation coefficient, can be calculated from the Equation (4.13),

$$r_s = 1 - \frac{6 \times \sum(R_X - R_Y)}{n(n^2 - 1)} \tag{4.13}$$

where r_s is the Spearman's correlation coefficient, R_X and R_Y are the ranks of each X and Y variable, and n is the sample size. Spearman correlation coefficient explains whether the variable X is increasing or decreasing while the variable Y is increasing or decreasing rather than explaining a linear relationship as it is in Pearson's correlation (Sheskin, 2000).

4.3.2.3. Calculation of the Significance of Correlation. In order to investigate if the relation between two variables is significant or not, the p-value is calculated to determine the significance. As stated by Sarabia *et al.* (2008), the two-tail test explained below can be applied for checking the significance of the correlation.

- H_0: X and Y are independent of each other
- H_a: There is a trend of matching the larger values of X with Y or the smaller values of X with Y

In order to calculate the p-value, the t-value shown in Equation (4.14) can be used if the sample size is greater than 10,

$$t_c = \frac{r_s\sqrt{n-2}}{\sqrt{1-r_s^2}} \tag{4.14}$$

where r_s is the Spearman's correlation coefficient, n is the sample size and t_c is the t-value (Sheskin, 2000).

4.3.3. One-Way and Two-Way ANOVA

In this study, one-way and two-way Analysis of Variance (ANOVA) was used. The ANOVA assumptions were tested by using Anderson-Darling normality test, Bartlett's test or Levene's test depending on the normality of the residuals, and by examining the residual plots of the ANOVA output in Minitab. When the assumptions for the one-way ANOVA were not satisfied, log(Y), sqrt(Y), and 1/Y transformations were applied. If the assumptions were not satisfied, the one-way ANOVA alternative Kruskal-Wallis test was used. For the two-way ANOVA used in this study, log(Y), sqrt(Y), and 1/Y transformations were applied until the assumptions of ANOVA was satisfied. However, if the assumptions were not fulfilled yet, the data were ranked ANOVA was applied on the ranked data. The ANOVA assumptions, Anderson-Darling normality test, Bartlett's test, Levene's test, transformations, Kruskal-Wallis test and ANOVA on ranks are explained below.

4.3.3.1. Assumptions of ANOVA. As stated by Roussas (2003), different groups can be compared and evaluated by using the technique ANOVA, which is a strong method. The assumptions of the ANOVA are as stated below (Sokal and Rohlf, 1995).

- Samples for ANOVA should be randomly selected.
- The error terms should be normally distributed.
- The variance of each group should be equal.
- The error terms shouldn't be correlated with each other.

4.3.3.2. Anderson-Darling Normality Test. The normality of the error terms was measured by Anderson-Darling Normality test. The statistics for Anderson-Darling is calculated from the Equation (4.15),

$$A_n^2 = -n - \frac{1}{n}\sum_i (2i-1)[logF^*(X_i) + \log(1 - F^*(X_{n+1-i})] \tag{4.15}$$

where A_n^2 is the Anderson-Darling test statistic, n is the sample size, $F^*(X_i)$ is the cumulative distribution function of the distribution selected and X_i are the ordered data. The test statistic is compared with the critical value and then the p-value is obtained (Razali and Wah, 2011).

4.3.3.3. Bartlett's Test and Levene's Test. The tests for equal variances both for Bartlett's Test and Levene's Test are applied by considering the hypothesis test explained in Equation (4.16), where σ_i^2 denotes the variance of each sample from 1 to k. (Montgomery, 2001)

$$\begin{aligned} H_0&: \sigma_1^2 = \sigma_2^2 = \cdots \sigma_k^2 \\ H_a&: At\ least\ one\ \sigma_i^2\ is\ different \end{aligned} \tag{4.16}$$

Bartlett's test statistic is calculated from Equation (4.17),

$$\chi_0^2 = 2.3026 \frac{(N_T - k)log_{10}\left(\frac{\sum_{i=1}^k (n_i - 1)V_i^2}{N_T - k}\right) - \sum_{i=1}^k (n_i - 1)log_{10}V_i^2}{1 + \frac{1}{3(k-1)}\left(\sum_{i=1}^k (n_i - 1)^{-1} - (N_T - k)^{-1}\right)} \tag{4.17}$$

where χ_0 is the Bartlett's test statistic, k is the number of random samples, V_i^2 is the sample variance of population i, and N_T is the total number of observations (Montgomery, 2001).

When the data are not normally distributed, Levene's test modified version can be used instead of Bartlett's test. The modified version of the Levene's test checks the absolute deviation of the difference between the median of the treatment and investigates if

the differences are same or not for all treatments (Montgomery, 2001 summarized from Levene, 1960 and Conover *et al.*, 1981).

4.3.3.4. Transformations. The transformations applied to satisfy the ANOVA assumptions in this study were natural logarithm transformation, also denoted as log(Y), square root transformation, shown as sqrt(Y), and 1/Y transformation since they were one of the common transformations. In order to avoid the values with zeros, +1 was added before transformation to the weighted score values. As stated by Belle *et al.* (2004), in case of occurrence of zeros, the transformations log(Y+1) and $\frac{1}{Y+1}$ can be used instead of log(Y) and 1/Y transformations, respectively.

4.3.3.5. Kruskal Wallis Test. The one-way ANOVA alternative Kruskal-Wallis test's test statistic calculation is as explained at the steps below. The Equations (4.18), (4.19), and (4.20) show the test statistic calculation steps and the Equation (4.21) shows the test statistic calculation method if there are no ties. In Equation (4.18), all ranks' mean sum of square value is calculated, and in Equation (4.19), each levels' mean sum of squares calculation is shown. In Equation (4.20), the Equation (4.19) is divided by the Equation (4.18) in order to find the test statistic,

$$S_r^2 = \frac{1}{n-1}\left(\sum\nolimits_{ij} r_{ij}^2 - \frac{n(n+1)^2}{4}\right) \tag{4.18}$$

$$S_t^2 = \left(\sum_{i=1}^{t} \frac{\left(\sum_{j=1}^{n_i} r_{ij}\right)^2}{n_i}\right) - \frac{1}{4}\, n(n+1)^2 \tag{4.19}$$

$$H_{test} = \frac{S_t^2}{S_r^2} \tag{4.20}$$

$$H_{test*} = \frac{12}{n(n+1)}\left(\sum_{i=1}^{t} \frac{\left(\sum_{j=1}^{n_i} r_{ij}\right)^2}{n_i}\right) - 3(n+1) \tag{4.21}$$

where S_r^2 is all rank's mean sum of square value, S_t^2 is each levels' mean sum of square value, H_{test} is the test statistic to be used when there are ties, H_{test*} is the test statistic when there are no ties t is number of independent samples having sizes of n_i, n is the total sample size ($n = \sum n_t$), and r_{ij} is the rank of each variable. If the test statistics H_{test} or H_{test*} are greater than the χ^2 critical value with t-1 degrees of freedom and selected significance level the null hypothesis is rejected and it is concluded that there is a significant difference between the factor levels (Sarabia *et al.,* 2008).

4.3.3.6. ANOVA on Ranks. In this study, when the assumptions of ANOVA couldn't be satisfied even after the log(Y), sqrt(Y) and 1/Y transformations, the data were ranked and ANOVA was applied on the ranked data. As stated by Sokal and Rohlf (1995), if the ANOVA assumptions couldn't be satisfied even though transformations were applied, the non-parametric methods can be applied.

The data in the study were ranked by using the following procedure: The smallest weighted score was given the smallest rank (rank 1), and all the outputs were ranked in an increasing order. If there were ties, an average number were given to them. After that, ANOVA was applied on the ranked data. Conover and Iman (1981) stated that the F-test could be used instead of using the H_{test} value used in Kruskal-Wallis test and stated the F-statistic on ranks can be rewritten as a function of H_{test} value used in Kruskal-Wallis test. Bu using the equation (4.20) and ranked F-test value F_R , Equation (4.22) is formed,

$$F_R = \frac{H_{test}/(t-1)}{(n-1-H_{test})/(n-t)} \tag{4.22}$$

where F_R is the F-test statistic of the ranked data, H_{test} is the Kruskal-Wallis test statistic, and t-1 is the degrees of freedom.

4.3.4. Post-Hoc Analysis with Bonferroni P-value Adjustment Method

After ANOVA was performed for the weighted score outputs with the factors of first instrument group and experience level, the pairwise comparisons with Bonferroni

corrected p-values were made for post-hoc analysis. The p-value adjustment of Bonferroni is made as shown Equation (4.23),

$$\pi^* = \pi \times m \tag{4.23}$$

where π^* is the adjusted p-value of the comparison, π is the p-value of the comparison, and m is the number of multiple comparisons (Dinno, 2015).

4.3.5. Logistic Regression

Logistic Regression was used in order to investigate the factors affecting the prevalence and the musical performance interferences of the musical instrument playing related symptoms. For each outcome, the data were split into two sets of train and test set which had ratios of 75% and 25% respectively and all the models were developed with the train sets and tested with the test sets. For the outputs of prevalence of neck, ears, right and left shoulder, and upper and lower back and the musical performance interferences of total body, neck, right and left shoulder, upper back, and lower back, a first model was developed by applying a backward stepwise logistic regression with all the factors. Following this step to simplify the models found, a second model was developed by applying the backward stepwise logistic regression with the factors found to be significant from the first model. If there were still insignificant factors in the second model, for simplification, a third model was developed.

The backward stepwise logistic regression procedure was based on the Akaike Information Criterion (AIC) values, and the model with the smallest AIC value was selected to be the best model. For the comparison of the two or three models for each output, the Area Under the Receiver Operating Characteristics (ROC) graph was used, which is called as AUC. From the two or three models developed for each output, the model with the largest test set AUC value was selected to be the perfect model. The Logistic Regression, AIC, ROC graph, and AUC are explained briefly below.

For each output, after each model was developed and tested by AUC statistic, the test and training tests were combined together and the final models of logistic regression were developed on complete data. Since the prediction capacity of each output was shown by AUC value, the prediction capacities of the final models were considered to be better than the models developed with train set, theoretically.

4.3.5.1. Logistic Regression. Logistic regression is a technique that investigates the effect of continuous or categorical variables on a binary or categorical variable. In logistic regression, a logit transformation is applied to the odds of an event. The odds of an event is simply the ratio of the probability of the event happening to the probability of the event is not happening. Thus, the logistic regression formula can be illustrated as Equation (4.24) (Peng *et al.*, 2002).

$$logit(Y) = ln\left(\frac{p}{1-p}\right) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n \tag{4.24}$$

The terms in Equation (4.24) are as the following: $ln\left(\frac{p}{1-p}\right)$ is the natural logarithm of the odds, also called the log-odds, $X_1, X_2, \ldots, X_n$ are the independent variables, α is the intercept, $\beta_1, \beta_2, \ldots, \beta_n$ are the regression coefficients, and $logit(Y)$ is the logit transformation applied. From the Equation (4.24), we can find p, which is the probability of the event happening as in the Equation (4.25).

$$p = \frac{e^{\alpha+\beta_1 X_1+\beta_2 X_2+\cdots+\beta_n X_n}}{1 + e^{\alpha+\beta_1 X_1+\beta_2 X_2+\cdots+\beta_n X_n}} \tag{4.25}$$

The Maximum Likelihood Estimation (MLE) is used for estimating the intercept α and coefficients $\beta_1, \beta_2, \ldots, \beta_n$, the values of the intercept and the coefficients are selected to maximize the likelihood function (Peng *et al.* 2002).

The backward stepwise regression was used for choosing the best model with the selected factors and the best model was selected to be the model with the lowest AIC value. According to Agresti (2002), one of the best estimators for selecting the best model

is the AIC value. The AIC value points out the difference between the estimated values and the exact values, and calculated from the formula,

$$AIC = -2(L(\hat{t}) - n_p) \tag{4.26}$$

where $L(\hat{t})$ is the maximized log-likelihood function and n_p is the number of parameters in the model (Agresti, 2002).

4.3.5.2. ROC Graph and AUC Statistic. In order to select and evaluate the classifiers, the ROC Graph can be used as a method. The classifiers were assessed by investigating their actual and predicted values. There are four possible outcomes in the classification, which are true positives, false negatives, true negatives and false positives. True positives' actual and predicted values are positive while false negatives' actual values are positive and predicted values are negative. True negatives' actual values are negative and predicted as negative while the false positives' actual values are positive and predicted as negative. From these four values, a confusion matrix is formed for further analysis (Fawcett, 2006). In Table 4.3, a confusion matrix is shown and TN, FN, FP, TP, N and P stand for the number of true negatives, false negatives, false positives, true positives, negatives, and positives respectively.

Table 4.3. The confusion matrix (Fawcett, 2006)

Confusion Matrix		**Actual Values**	
		False	**True**
Values Classified by Prediction	**N**	TN	FP
	P	FN	TP

From the values shown in Table 4.3, the false positive rate which is also called 1-specifity and the true positive rate, also called as sensitivity, can be calculated from the Equations (4.27) and (4.28), respectively.

$$False\ positive\ rate = \frac{FP}{N} = 1 - specifity \tag{4.27}$$

$$True\ positive\ rate = \frac{TP}{P} = sensitivity \tag{4.28}$$

The ROC graph's axes are false positive rate and true positive rate as calculated from Equations (4.27) and (4.28). An example ROC graph is shown in Figure 4.4. In order to select a classifier, a point on the ROC is selected, however, depending on the location of the classifier, the performance is affected. It is preferred to select a classifier having high true positive rates and lower false positive rates, therefore, in order to be able to select that classifier, the ROC curve should be close to the upper left corner (Fawcett, 2006).

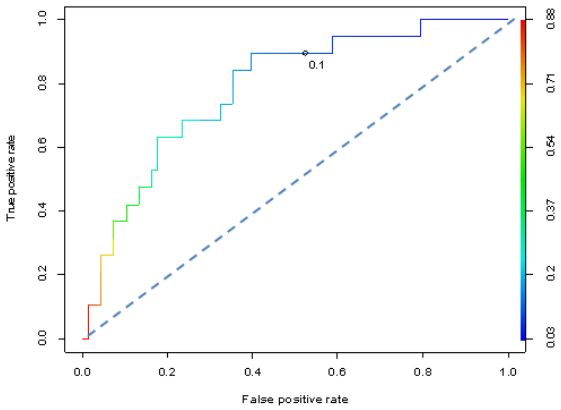


Figure 4.4. An example ROC graph

In order to evaluate classifier performance, the AUC value can be used. AUC is the ratio of the area under the ROC curve, and it has values between 0 and 1. A rational classifier should have values greater than 0.5, because having an AUC value of 0.5 results in classifying randomly. (Fawcett, 2006). The AUC value can be calculated from the Equation (4.29),

$$AUC = \frac{n_{(-)}n_{(+)} - \left(R_0 - \frac{1}{2}n_{(-)}\left(n_{(-)} + 1\right)\right)}{n_{(-)}n_{(+)}} \tag{4.29}$$

where $n_{(-)}$ and $n_{(+)}$are the sample sizes for negatives and positives, and R_0 is the negative samples' sum of ranks (Greiner *et al.*, 2000)

4.3.6. Ratio Scaling

Since the hand dimensions were taken from a small number of subjects, the data were enlarged to the other musicians by applying the Ratio Scaling method in order to perform better analysis. According to Pheasant (2003), if there are two samples of people and there is a missing data at the first sample, the missing part of that data can be estimated by using a common information for both samples and the values from the second sample can be used in order to scale and estimate the missing data at the first sample. However, when applying Ratio Scaling method, it should be noted that both samples of people should have the same sex, age, and ethnic background. Height is the parameter used oftenly for scaling. The Ratio Scaling equations are shown in Equations (4.30), (4.31), (4.32), and (4.33).

$$\frac{\mu_{Y1}}{\mu_{X1}} \cong \frac{\mu_{Y2}}{\mu_{X2}} \tag{4.30}$$

$$\frac{\sigma_{Y1}}{\sigma_{X1}} \cong \frac{\sigma_{Y2}}{\sigma_{X2}} \tag{4.31}$$

$$C_1 = \frac{\mu_{Y1}}{\mu_{X1}} \tag{4.32}$$

$$C_2 = \frac{\sigma_{Y1}}{\sigma_{X1}} \tag{4.33}$$

In Equations (4.30), (4.31), (4.32), and (4.33), X_1 and X_2 are the known scaling parameters of the first and second population respectively, Y_1 is the known parameter to be scaled of the first populations and Y_2 is the unknown parameter of the second population. μ_{X1}, μ_{X2}, μ_{Y1}, and μ_{Y2} are the means and σ_{X1}, σ_{X2}, σ_{Y1}, and σ_{Y2} are the standard deviations of these parameters respectively. The coefficients of C_1 and C_2 can be used for scaling the mean and the standard deviations. These coefficients can easily be multiplied by the scaling parameter, such as height, in order to apply Ratio Scaling (Pheasant, 2003).

4.3.7. Factors Investigated in Statistical Analyses

In the statistical analyses performed, the response and the classification variables used for ANOVA and Logistic Regression are as shown in Table 4.4. The response variables were determined according to the largest weighted scores for all instruments and for each instrument groups, respectively. For hand dimension correlations, the dependent and independent variables are as shown in Table 4.5.

Table 4.4. Response and independent variables used in ANOVA and Logistic Regression

Statistical Analysis	Independent Variables	Response Variables
ANOVA	➢ First Instrument Group (Brass, Keyboard, Plucked Strings, Strings, Woodwind, Drums and Percussion) ➢ Experience Level (≤ 5 years, 6-10 years, 11-20 years, 21+ years) ➢ Gender* *Separate ANOVAs were performed for each gender)	➢ Total Body WS ➢ Ears WS ➢ Neck WS ➢ Right Shoulder WS ➢ Left Shoulder WS ➢ Upper Back WS ➢ Lower Back WS ➢ Right Bottom of Thumb WS ➢ Left Bottom of Thumb WS ➢ Right Thumb WS ➢ Left Thumb WS ➢ Right Wrist WS ➢ Left Wrist WS ➢ Right Palm WS ➢ Mouth/Lips WS ➢ Face/Jaws WS ➢ Teeth WS ➢ Left Elbow WS ➢ Right Pinkie WS
Logistic Regression	➢ Gender ➢ BMI ➢ Sleeping Hours ➢ Weekly Time Spent Playing ➢ Practice Session Duration ➢ Rest Duration ➢ Daily Stress ➢ Musical Performance Stress ➢ Daily Computer Usage ➢ Daily Cell-Phone Usage ➢ Occupation ➢ Playing more than One Instrument ➢ Warming Up ➢ Experience Level ➢ Regular Exercise each Week	➢ Ears Prevalence ➢ Neck Prevalence ➢ Right Shoulder Prevalence ➢ Left Shoulder Prevalence ➢ Upper Back Prevalence ➢ Lower Back Prevalence ➢ Total Body Perf. Interference ➢ Neck Perf. Interference ➢ Right Shoulder Perf. Interference ➢ Left Shoulder Perf. Interference ➢ Upper Back Perf. Interference ➢ Lower Back Perf. Interference

Table 4.5. Dependent and independent variables used in correlation of hand dimensions

Statistical Analysis	**Independent Variables (Hand Dimensions)**	**Dependent Variables (Weighted Scores)**
Correlation of Hand Dimensions	➢ Right Hand Span ➢ Left Hand Span ➢ Right Thumb and Index Finger Span ➢ Left Thumb and Index Finger Span ➢ Right Hand Length ➢ Left Hand Length ➢ Right Hand Breadth ➢ Left Hand Breadth ➢ Right Thumb Length ➢ Right Index Finger Length ➢ Right Middle Finger Length ➢ Right Ring Finger Length ➢ Right Pinkie Length ➢ Left Thumb Length ➢ Left Index Finger Length ➢ Left Middle Finger Length ➢ Left Ring Finger Length ➢ Left Pinkie Length ➢ Right Thumb Width ➢ Right Index Finger Width ➢ Right Middle Finger Width ➢ Right Ring Finger Width ➢ Right Pinkie Width ➢ Left Thumb Width ➢ Left Index Finger Width ➢ Left Middle Finger Width ➢ Left Ring Finger Width ➢ Left Pinkie Width	➢ Total Body WS ➢ Ears WS ➢ Neck WS ➢ Right Shoulder WS ➢ Left Shoulder WS ➢ Upper Back WS ➢ Lower Back WS ➢ Right Thumb WS ➢ Left Thumb WS ➢ Right Index Finger WS ➢ Left Index Finger WS ➢ Right Middle Finger WS ➢ Left Middle Finger WS ➢ Right Ring Finger WS ➢ Left Ring Finger WS ➢ Right Pinkie WS ➢ Left Pinkie WS ➢ Right Palm WS ➢ Left Palm WS ➢ Right Bottom of Thumb WS ➢ Left Bottom of Thumb WS

5. RESULTS

5.1. Results of the Survey

Total of 372 participants were involved in the survey in order to collect information about musical instrument playing related musculoskeletal symptoms. 24 subjects were excluded from the study since 13 of them had missing information. Also, 11 subjects had previous injuries which were not related with musical instrument playing and injuries were affecting the playing related symptom affected body parts, hence they were excluded as well. Thus, 348 participants' data were analyzed in the study.

5.1.1. Subjects

The 348 subjects consisted of amateur and professional musicians, music students, music teachers, university lecturers and people having different professions. The participants had an age range between 16 to 66 and they had experience level of playing instruments varying between 1 and 57 years. The subjects were from different regions of Turkey, and there were also participants from foreign countries. The family origin distribution of the participants is shown in Figure 5.1. and Table 5.1.

Table 5.1. The family origin distribution of the participants

Region/Country	**Number of Participants**
Aegean	35
Black Sea	57
Central Anatolia	61
Eastern Anatolia	31
Marmara	121
Mediterranean	19
Southeast Anatolia	6
Not Stated	8
Foreign Countries	10
Total	**348**

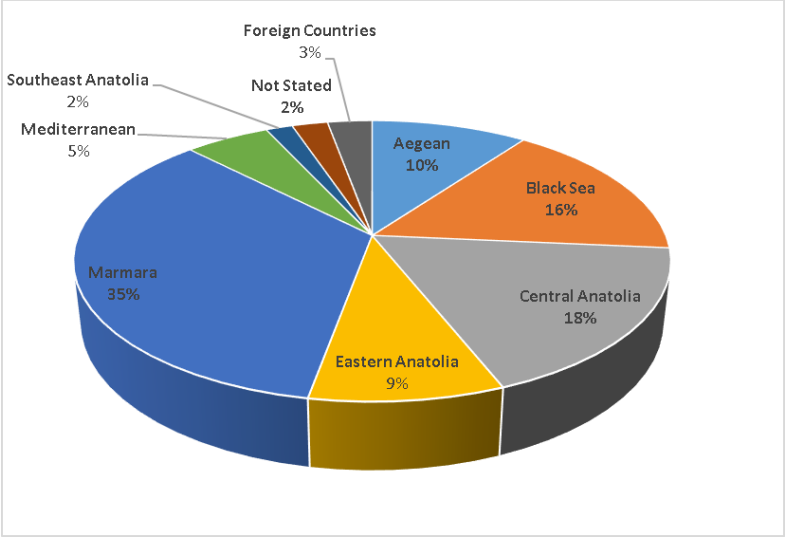


Figure 5.1. The family origin distribution percentages of the participants

The first and second instruments played by the subjects are illustrated in Tables 5.2 and 5.3 respectively. For the first instrument group, instruments from brass, and drums & percussion instrument families were only played by male subjects. Females were only playing instrument from keyboard, plucked strings, strings and woodwind instrument families. There were also local instruments which are being played by the subjects. The local instruments played as first and second instruments and the number of the local instruments were shown separately in Table 5.4.

5.1.2. Descriptive Statistics

The mean, standard deviation, minimum, maximum and range values of the continuous variables of 348 subjects participated the survey are as stated in Table 5.5. The participant group consisted of 181 males and 167 females.

The categorical variables of the survey are stated in Table 5.6. Some of the continuous variables were split into groups for better evaluation and group comparisons. For instance, the age was divided into five groups of 16-25, 26-35, 36-45, 46-55, and 56-66. The experience values of the participants were having values from 1 to 57, and the experience was divided into 4 groups which are less than or equal to five years, 6-10 years, 11-20 years, and 21+ years.

Table 5.2. The first instruments played by the subjects

First Instrument Group	First Instrument Name	Number	Total
Brass	French Horn	1	**23**
	Trombone	3	
	Trumpet	18	
	Tuba	1	
Drums and Percussion	Drums	22	**31**
	Darbouka	9	
Keyboard	Keyboard/Synth	4	**71**
	Piano	67	
Plucked Strings	Harp	1	**97**
	Bass Guitar	6	
	Electric Guitar	3	
	Guitar	47	
	Classical Guitar	5	
	Mandolin	1	
	Tambur	4	
	Ukulele	1	
	Bağlama	17	
	Kanoon	1	
	Ud	11	
Strings	Cello	4	**66**
	Violin	45	
	Viola	13	
	Kemençe	1	
	Classical kemençe	3	
Woodwind	Alto Saxophone	1	**60**
	Bassoon	1	
	Flute	4	
	Oboe	9	
	Transverse Flute	26	
	Clarinet	15	
	Saxophone	4	
		Total	**348**

The subjects were asked if they were experiencing musical instrument playing related symptoms at their body parts or not. If subjects were not experiencing symptoms at a part of their body, they marked “never” on the survey, but if the subjects were experiencing any symptoms, they were asked to state the frequency, severity and musical performance interference level. The number of participants selected the frequency, severity and musical performance interference level for each body part is shown in Table 5.7. After the weighted scores were assigned to each body part, the five mostly affected body parts were found out to be neck, upper back, left shoulder, lower back and right shoulder respectively based on their weighted scores. Later, the analysis will be based on the total body weighted score and mostly affected body parts. Although the subjects were not experiencing symptoms at ears as much as the mostly affected five body parts, ears were added to the body parts to be investigated because for musical instrument playing ears have an important role. The body parts that the participants were mostly experiencing symptoms are also stated in Table 5.7.

Table 5.3. The second instruments played by the subjects

Second Instrument Group	Second Instrument Name	Number	Total
Drums and Percussion	Drums	2	**5**
	Percussion	2	
	Darbouka	1	
Keyboard	Accordion	2	**102**
	Keyboard/Synth	10	
	Piano	90	
Plucked Strings	Acoustic Guitar	1	**39**
	Harp	1	
	Bass Guitar	1	
	Electric Guitar	1	
	Guitar	32	
	Classical Guitar	1	
	Baglama	2	
Strings	Cello	1	**8**
	Violin	3	
	Contrabass	1	
	Viola	1	
	Classical kemençe	1	
	Rebab	1	
Woodwind	Kazoo	1	**5**
	Harmonica	1	
	Transverse flute	3	
		Total	**159**

Table 5.4. The local instruments played by the subjects

Local Instruments Played as First Instruments	**Number**	**Local Instruments Played as Second Instruments**	**Number**
Darbouka	9	Darbouka	1
Baglama	17	Baglama	2
Tambur	4	Classical kemençe	1
Ud	11	Rebab	1
Kemençe	1		
Classical kemençe	3		
Kanoon	1		
Total	**46**	**Total**	**5**
First Instrument Local/All	**13.2%**	**Second Instrument Local/All**	**3.1%**

Table 5.5. The survey results of continuous variables

Variable	Females (n=167)				Males (n=181)			
	Mean	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
BMI	20.82	2.28	16.14	28.93	24.88	2.57	17.21	33.90
Hours Spent for Sleeping	7.77	0.99	5	12	7.47	1.02	5	12
Experience (years)	18.18	13.77	1	57	16.65	11.50	1	50
Weekly Time Spent Playing(hours)	15.81	11.58	0.1	50	13.63	9.71	0.35	70
Practice Session Duration (mins)	52.65	21.74	20	120	58.70	31.44	10	240
Rest Duration (mins)	18.94	11.79	0	60	21.38	29.66	0	360
Age (years)	33.46	13.35	16	64	31.56	12.32	16	66
Daily Stress Level (1 to 5)	2.78	0.90	1	5	2.62	1.03	1	5
Musical Performance Stress Level (1 to 5)	3.21	1.11	1	5	2.98	1.05	1	5
Daily Computer Usage (hours)	2.84	2.46	0	12	3.50	2.92	0	15
Daily Cell Phone Usage (hours)	2.48	1.54	0	8	2.66	1.53	0	9
Cigarette Package per Day	0.27	0.46	0	1.5	0.34	0.54	0	2
Alcohol per Week	0.54	0.79	0	5	0.95	1.17	0	7

Besides the calculation of the weighted scores, the prevalence ratios of playing related symptoms were calculated. If a body part's frequency was stated to be different than "never", subjects were considered to be experiencing symptoms at that body part. However, if "never" was selected, it was meaning that subjects weren't experiencing symptoms. The prevalence of the total body was existing if the subjects were experiencing symptoms at least one of the body part.

Moreover, the performance effects of playing related symptoms were found out from the survey results. If a subject stated the musical performance interference as "not at all", for a body part, it was concluded that while using the related body part to play the musical instrument, the musical performance wasn't affected. Also, if the subject stated the frequency of experiencing symptoms as "never", the performance was considered to be unaffected as well. The total body musical instrument playing was found out to be unaffected if a subjects' total body prevalence is zero or none of the body parts' symptoms were interfering the musical performance. The prevalence ratios and the musical performance interferences of total body and all body parts for all instrument groups are illustrated in Table 5.8. The weighted scores, prevalence ratios and the musical performance interferences of participants according to gender are shown in Table 5.9, Table 5.10, Table 5.11, respectively. The same tables according to the experience levels are shown in Table 5.12, Table 5.13 and Table 5.14, respectively, and the tables according

to the first instrument groups are shown in Table 5.15, Table 5.16, and Table 5.17, respectively.

Table 5.6. The survey results of categorical variables

Females (n=167)			**Males (n=181)**		
Categorical Variable			**Categorical Variable**		
Occupation	**n**	**(%)**	**Occupation**	**n**	**(%)**
Music Related	110	65.87%	Music Related	104	57,46%
Not Music Related	57	34.13%	Not Music Related	77	42,54%
Age Group	**n**	**(%)**	**Age Group**	**n**	**(%)**
16-25	58	34.73%	16-25	66	36,46%
26-35	44	26.35%	26-35	61	33,70%
36-45	28	16.77%	36-45	26	14,36%
46-55	23	13.77%	46-55	15	8,29%
56-66	14	8.38%	56-66	13	7,18%
Smoking	**n**	**(%)**	**Smoking**	**n**	**(%)**
No	112	67.07%	No	115	63.54%
Yes	55	32.93%	Yes	66	36.46%
Alcohol	**n**	**(%)**	**Alcohol**	**n**	**(%)**
No	85	50.90%	No	69	38.12%
Yes	82	49.10%	Yes	112	61.88%
Dominant Hand	**n**	**(%)**	**Dominant Hand**	**n**	**(%)**
Either	15	8.98%	Either	7	3.87%
Left	18	10.78%	Left	22	12.15%
Right	134	80.24%	Right	152	83.98%
First Instrument Group	**n**	**(%)**	**First Instrument Group**	**n**	**(%)**
Keyboard	41	24.55%	Brass	23	12.71%
Plucked Strings	38	22.75%	Drums and Percussion	31	17.13%
Strings	48	28.74%	Keyboard	30	16.57%
Woodwind	40	23.95%	Plucked Strings	59	32.60%
			Strings	18	9.94%
			Woodwind	20	11.05%
Second Instrument Group	**n**	**(%)**	**Second Instrument Group**	**n**	**(%)**
Keyboard	57	34.13%	Drums and Percussion	5	2.76%
Plucked Strings	15	8.98%	Keyboard	45	24.86%
Strings	4	2.40%	Plucked Strings	24	13.26%
Woodwind	3	1.80%	Strings	4	2.21%
Not playing second instrument	88	52.69%	Woodwind	2	1.10%
			Not playing second instrument	101	55.80%

Table 5.6. The survey results of categorical variables (cont.).

Females (n=167)			Males (n=181)		
Categorical Variable			**Categorical Variable**		
Playing more than 1 instrument	**n**	**(%)**	**Playing more than 1 instrument**	**n**	**(%)**
No	88	52.69%	No	101	55.80%
Yes	79	47.31%	Yes	80	44.20%
Warming Up	**n**	**(%)**	**Warming Up**	**n**	**(%)**
No	89	53.29%	No	96	53.04%
Yes	78	46.71%	Yes	85	46.96%
Injury Preventive Education	**n**	**(%)**	**Injury Preventive Education**	**n**	**(%)**
No	152	91.02%	No	171	94.48%
Yes	15	8.98%	Yes	10	5.52%
Past Injury	**n**	**(%)**	**Past Injury**	**n**	**(%)**
No	116	69.46%	No	121	66.85%
Yes	51	30.54%	Yes	60	33.15%
Music Type Played	**n**	**(%)**	**Music Type Played**	**n**	**(%)**
Including classical	145	86.83%	Including classical	72	39.78%
Not including classical	22	13.17%	Not including classical	109	60.22%
First Instrument Origin	**n**	**(%)**	**First Instrument Origin**	**n**	**(%)**
Other	151	90.42%	Other	151	83.43%
Turkish	16	9.58%	Turkish	30	16.57%
Regular Exercise Each Week	**n**	**(%)**	**Regular Exercise Each Week**	**n**	**(%)**
No	63	37.72%	No	77	46.11%
Yes	104	62.28%	Yes	104	62.28%
Experience	**n**	**(%)**	**Experience**	**n**	**(%)**
Less than or equal to five years	31	18.56%	Less than or equal to five years	31	17.13%
6-10 years	38	22.75%	6-10 years	42	23.20%
11-20 years	37	22.16%	11-20 years	54	29.83%
21+ years	61	36.53%	21+ years	54	29.83%

The survey results pointed out that body parts which participants were mostly affected by playing related symptoms were different at each instrument type. For each instrument type, the most affected five body regions were determined according to their weighted scores. For keyboard instrument group, the mostly affected five body regions were neck, right bottom of thumb, lower back, right thumb and left bottom of thumb respectively. For drums and percussion group, these body regions were lower back, right wrist, left wrist, right palm and ears respectively. Brass instrument players had symptoms mostly at mouth/lips, face/jaws, teeth, neck and right bottom of thumb and plucked instrument players had symptoms at left bottom of thumb, left shoulder, left thumb, neck and left wrist. String players had symptoms mostly at neck, upper back, right and left shoulder and left elbow while woodwind players stated that they experienced symptoms at neck, right pinkie, right shoulder, mouth/lips and right wrist. The mostly affected five body regions for each instrument family is illustrated in Figure 5.2. Moreover, Figure 5.3 shows

the mostly affected five body parts according to gender, and Figure 5.4 and Figure 5.5 show the mostly affected five body parts according to the instrument groups played by females and males, respectively. Furthermore, Figure 5.6 illustrates the mostly affected five body parts according to the experience level groups.

Table 5.7. The number of stated levels of symptom frequency, severity and musical performance interference and the weighted scores of the body parts

	Frequency					Severity			Musical Performance			Weighted Score	
Body Parts	**Never**	**1-2 times**	**3-4 times**	**Once every day**	**Several times every day**	**Slightly**	**Moderately**	**Severely**	**Not at all**	**Slightly**	**Substantially**	**Mean**	**SD**
Neck	**131**	**114**	**72**	**21**	**10**	**123**	**81**	**13**	**133**	**70**	**14**	**5.039**	**10.338**
Upper back	**174**	**112**	**40**	**10**	**12**	**110**	**56**	**7**	**123**	**47**	**4**	**3.282**	**8.749**
Left shoulder	**197**	**93**	**43**	**5**	**10**	**100**	**42**	**8**	**104**	**40**	**6**	**3.106**	**9.510**
Lower back	**174**	**111**	**46**	**12**	**5**	**109**	**61**	**4**	**118**	**52**	**4**	**2.848**	**6.191**
Right shoulder	**196**	**103**	**37**	**4**	**8**	**111**	**37**	**4**	**107**	**43**	**3**	**2.655**	**8.397**
Left bottom of thumb	213	85	39	4	7	100	27	8	93	37	5	2.628	9.158
Right wrist	237	66	35	5	5	82	25	4	69	36	6	2.266	8.210
Left wrist	218	90	31	5	4	97	30	3	81	45	4	2.029	5.905
Left thumb	237	83	22	3	3	82	24	5	69	35	7	2.029	8.781
Right thumb	226	92	26	0	4	90	28	4	84	35	3	1.977	7.728
Right bottom of thumb	241	71	29	3	4	87	16	4	81	20	6	1.746	6.656
Left forearm	229	71	41	5	2	96	21	2	88	27	4	1.624	4.927
Right upper arm	213	102	26	5	2	105	27	1	100	33	1	1.375	3.369
Left index finger	274	51	14	3	6	58	14	2	52	17	5	1.345	6.536
Left upper arm	261	57	21	4	5	65	19	3	67	18	2	1.305	5.682
Mouth/Lips	276	35	25	10	2	53	18	1	46	23	3	1.297	4.148
Right pinkie	297	33	13	1	4	29	17	4	33	13	4	1.191	6.458
Right forearm	244	71	28	5	0	84	18	1	83	18	3	1.138	3.091
Left ring finger	289	40	13	3	3	44	14	1	39	16	4	1.119	6.232
Ears	**271**	**43**	**29**	**2**	**3**	**64**	**9**	**4**	**67**	**9**	**1**	**1.101**	**5.527**
Left pinkie	278	48	16	4	2	51	17	2	44	21	3	1.072	3.906
Left elbow	305	30	7	2	4	30	11	2	31	10	2	1.068	7.323
Left palm	287	45	10	4	2	43	15	3	40	19	2	1.043	4.467
Face/Jaws	257	62	27	1	1	69	20	2	69	22	0	1.026	3.025
Right elbow	302	28	13	3	2	28	15	3	29	15	2	1.007	5.817
Right palm	309	22	10	4	3	26	12	1	22	14	3	0.940	5.697
Left middle finger	292	37	12	4	3	45	11	0	40	14	2	0.848	4.009
Right index finger	292	46	6	2	2	46	10	0	44	10	2	0.572	2.319
Right ring finger	327	18	2	0	1	15	6	0	15	4	2	0.365	3.459
Teeth	314	22	9	3	0	31	3	0	28	6	0	0.335	1.564
Right foot/ankle	331	10	4	2	1	12	5	0	11	5	1	0.322	2.534
Hips/Buttocks	330	13	3	1	1	15	3	0	10	8	0	0.266	2.269
Left knee	334	9	3	1	1	10	3	1	10	4	0	0.264	2.090
Right middle finger	316	28	2	1	1	31	1	0	27	5	0	0.224	0.966
Left lower leg	341	5	1	0	1	6	0	1	5	2	0	0.126	1.638
Left foot/ankle	335	11	0	2	0	11	2	0	7	6	0	0.115	0.645
Right knee	335	12	0	1	0	11	2	0	8	5	0	0.105	0.626
Left Thigh	337	8	1	2	0	9	2	0	8	3	0	0.083	0.510
Right Thigh	341	7	0	0	0	5	2	0	3	4	0	0.060	0.466
Right lower leg	344	3	1	0	0	4	0	0	2	1	1	0.047	0.595

Table 5.8. The prevalence and musical performance interference ratios of total body and body parts for all instrument groups

Body Parts	Prevalence Ratio	Musical Performance Interference Ratio	Body Parts	Prevalence Ratio	Musical Performance Interference Ratio
Total Body	98.28%*[1]	66.09%*[2]	**Left pinkie**	20.11%	6.90%
Neck	62.36%*[3]	24.14%*[4]	**Left elbow**	12.36%	3.45%
Upper back	50.00%	14.66%	**Left palm**	17.53%	6.03%
Left shoulder	43.39%	13.22%	**Face/Jaws**	26.15%	6.32%
Lower back	50.00%	16.09%	**Right elbow**	13.22%	4.89%
Right shoulder	43.68%	13.22%	**Right palm**	11.21%	4.89%
Left bottom of thumb	38.79%	12.07%	**Left middle finger**	16.09%	4.60%
Right wrist	31.90%	12.07%	**Right index finger**	16.09%	3.45%
Left wrist	37.36%	14.08%	**Right ring finger**	6.03%	1.72%
Left thumb	31.90%	12.07%	**Teeth**	9.77%	1.72%
Right thumb	35.06%	10.92%	**Right foot/ankle**	4.89%	1.72%
Right bottom of thumb	30.75%	7.47%	**Hips/Buttocks**	5.17%	2.30%
Left forearm	34.20%	8.91%	**Left knee**	4.02%	1.15%
Right upper arm	38.79%	9.77%	**Right middle finger**	9.20%	1.44%
Left index finger	21.26%	6.32%	**Left lower leg**	2.01%	0.57%
Left upper arm	25.00%	5.75%	**Left foot/ankle**	3.74%	1.72%
Mouth/Lips	20.69%	7.47%	**Right knee**	3.74%	1.44%
Right pinkie	14.66%	4.89%	**Left Thigh**	3.16%	0.86%
Right forearm	29.89%	6.03%	**Right Thigh**	2.01%	1.15%
Left ring finger	16.95%	5.75%	**Right lower leg**	1.15%	0.57%
Ears	22.13%	2.87%			

*1 see eq. 4.10; *2 see eq. 4.11; *3 see eq. 4.6; *4 see eq. 4.7

Table 5.9. The weighted scores of total body and body parts according to the gender

Body Parts	Weighted Scores		Body Parts	Weighted Scores	
	Female	Male		Female	Male
Total Body	59.707	42.939	**Right Knee**	0.036	0.169
Ears	1.018	1.177	**Left Knee**	0.018	0.492
Face/Jaws	1.228	0.840	**Right Lower Leg**	0.009	0.083
Mouth/Lips	0.626	1.917	**Left Lower Leg**	0.039	0.207
Teeth	0.144	0.511	**Right Foot/Ankle**	0.407	0.243
Neck	8.108	2.207	**Left Foot/Ankle**	0.018	0.204
Right Shoulder	3.808	1.591	**Right Thumb**	2.332	1.649
Left Shoulder	4.063	2.224	**Left Thumb**	2.159	1.909
Upper Back	4.392	2.257	**Right Index Finger**	0.545	0.597
Right Upper Arm	2.260	0.558	**Left Index Finger**	0.958	1.702
Left Upper Arm	1.967	0.693	**Right Middle Finger**	0.240	0.210
Lower Back	2.835	2.859	**Left Middle Finger**	0.572	1.102
Right Elbow	1.344	0.696	**Right Ring Finger**	0.593	0.155
Left Elbow	1.419	0.743	**Left Ring Finger**	0.707	1.500
Right Forearm	1.269	1.017	**Right Pinkie**	2.189	0.271
Left Forearm	1.787	1.472	**Left Pinkie**	1.494	0.682
Right Wrist	3.159	1.442	**Right Palm**	0.835	1.036
Left Wrist	2.275	1.801	**Left Palm**	0.931	1.146
Hips/Buttocks	0.362	0.177	**Right Bottom of Thumb**	0.994	2.439
Right Thigh	0.090	0.033	**Left Bottom of Thumb**	2.422	2.818
Left Thigh	0.054	0.110			

Table 5.10. The prevalence of discomfort of total body and body parts according to the gender

Body Parts	Prevalence		Body Parts	Prevalence	
	Female	Male		Female	Male
Total Body	99.40%	97.24%	**Right Knee**	1.80%	5.52%
Ears	16.17%	27.62%	**Left Knee**	1.20%	6.63%
Face/Jaws	33.53%	19.34%	**Right Lower Leg**	0.60%	1.66%
Mouth/Lips	22.16%	19.34%	**Left Lower Leg**	1.80%	2.21%
Teeth	5.39%	13.81%	**Right Foot/Ankle**	3.59%	6.08%
Neck	74.25%	51.38%	**Left Foot/Ankle**	1.20%	6.08%
Right Shoulder	57.49%	30.94%	**Right Thumb**	43.11%	27.62%
Left Shoulder	52.69%	34.81%	**Left Thumb**	40.72%	23.76%
Upper Back	53.89%	45.86%	**Right Index Finger**	15.57%	16.57%
Right Upper Arm	54.49%	23.76%	**Left Index Finger**	19.16%	23.20%
Left Upper Arm	31.14%	19.34%	**Right Middle Finger**	6.59%	11.60%
Lower Back	47.31%	52.49%	**Left Middle Finger**	12.57%	19.34%
Right Elbow	15.57%	11.05%	**Right Ring Finger**	6.59%	5.52%
Left Elbow	12.57%	12.15%	**Left Ring Finger**	13.17%	20.44%
Right Forearm	31.74%	27.62%	**Right Pinkie**	21.56%	8.29%
Left Forearm	38.92%	29.83%	**Left Pinkie**	25.75%	14.92%
Right Wrist	32.34%	31.49%	**Right Palm**	6.59%	15.47%
Left Wrist	40.12%	34.81%	**Left Palm**	19.16%	16.02%
Hips/Buttocks	4.19%	6.08%	**Right Bottom of Thumb**	25.75%	35.36%
Right Thigh	2.40%	1.66%	**Left Bottom of Thumb**	37.13%	40.33%
Left Thigh	1.80%	5.52%			

Table 5.11. The musical performance interference at total body and body parts according to the gender

Body Parts	Musical Performance Interference		Body Parts	Musical Performance Interference	
	Female	Male		Female	Male
Total Body	68.86%	63.54%	**Right Knee**	0.60%	2.21%
Ears	2.40%	3.31%	**Left Knee**	0.00%	2.21%
Face/Jaws	8.38%	4.42%	**Right Lower Leg**	0.00%	0.55%
Mouth/Lips	7.19%	6.08%	**Left Lower Leg**	0.00%	1.10%
Teeth	0.00%	3.31%	**Right Foot/Ankle**	1.20%	1.66%
Neck	32.93%	8.29%	**Left Foot/Ankle**	0.00%	3.31%
Right Shoulder	13.17%	11.60%	**Right Thumb**	10.78%	9.39%
Left Shoulder	10.18%	12.71%	**Left Thumb**	11.98%	8.29%
Upper Back	13.77%	13.26%	**Right Index Finger**	2.99%	2.76%
Right Upper Arm	16.17%	2.76%	**Left Index Finger**	5.99%	3.87%
Left Upper Arm	7.19%	3.31%	**Right Middle Finger**	1.20%	1.66%
Lower Back	12.57%	17.13%	**Left Middle Finger**	2.40%	5.52%
Right Elbow	5.39%	3.31%	**Right Ring Finger**	0.60%	1.66%
Left Elbow	2.99%	2.76%	**Left Ring Finger**	3.59%	5.52%
Right Forearm	5.99%	4.42%	**Right Pinkie**	4.79%	2.76%
Left Forearm	8.98%	6.63%	**Left Pinkie**	7.19%	4.97%
Right Wrist	8.98%	11.60%	**Right Palm**	2.99%	4.97%
Left Wrist	13.17%	12.71%	**Left Palm**	4.79%	6.08%
Hips/Buttocks	3.59%	1.10%	**Right Bottom of Thumb**	3.59%	7.73%
Right Thigh	1.80%	0.55%	**Left Bottom of Thumb**	12.57%	8.84%
Left Thigh	0.60%	0.55%			

Table 5.12. The weighted scores of total body and body parts according to the experience levels

Body Parts	Weighted Scores			
	≤ 5 Years	6-11 years	11-20 years	21+ years
Total Body	46.177	45.725	46.681	60.643
Ears	0.274	0.669	0.593	2.248
Face/Jaws	0.766	1.288	0.874	1.104
Mouth/Lips	1.048	1.256	0.863	1.804
Teeth	0.153	0.375	0.242	0.478
Neck	6.000	3.750	3.209	6.865
Right Shoulder	1.790	1.281	2.407	4.274
Left Shoulder	2.395	1.813	2.115	5.174
Upper Back	1.798	3.688	3.082	3.957
Right Upper Arm	1.185	1.194	1.560	1.457
Left Upper Arm	0.613	1.344	0.692	2.135
Lower Back	2.274	2.663	2.670	3.426
Right Elbow	1.048	0.131	0.901	1.678
Left Elbow	0.556	0.381	1.445	1.522
Right Forearm	1.508	0.919	0.819	1.343
Left Forearm	1.218	1.938	1.412	1.791
Right Wrist	2.694	1.681	1.995	2.657
Left Wrist	1.855	1.994	2.659	1.648
Hips/Buttocks	0.694	0.131	0.181	0.196
Right Thigh	0.145	0.038	0.049	0.039
Left Thigh	0.169	0.019	0.115	0.057
Right Knee	0.194	0.038	0.165	0.057
Left Knee	0.024	0.744	0.236	0.083
Right Lower Leg	0.000	0.019	0.165	0.000
Left Lower Leg	0.000	0.394	0.137	0.000
Right Foot/Ankle	1.073	0.100	0.198	0.170
Left Foot/Ankle	0.000	0.138	0.214	0.083
Right Thumb	1.556	1.350	2.000	2.622
Left Thumb	3.331	2.450	0.901	1.926
Right Index Finger	0.637	0.194	0.901	0.539
Left Index Finger	0.798	1.606	1.901	1.017
Right Middle Finger	0.266	0.075	0.489	0.096
Left Middle Finger	0.839	1.200	0.555	0.839
Right Ring Finger	0.242	0.075	0.456	0.561
Left Ring Finger	0.621	2.319	0.879	0.743
Right Pinkie	1.694	1.413	1.099	0.839
Left Pinkie	1.379	1.206	0.874	0.970
Right Palm	0.782	0.594	0.896	1.300
Left Palm	0.976	1.256	1.819	0.317
Right Bottom of Thumb	1.613	1.100	2.500	1.670
Left Bottom of Thumb	1.968	2.906	2.412	2.961

Table 5.13. The prevalence of discomfort at total body and body parts according to the experience levels

Body Parts	Prevalence			
	≤ 5 Years	6-11 years	11-20 years	21+ years
Total Body	96.77%	98.75%	96.70%	100.00%
Ears	11.29%	18.75%	18.68%	33.04%
Face/Jaws	20.97%	23.75%	29.67%	27.83%
Mouth/Lips	17.74%	21.25%	23.08%	20.00%
Teeth	8.06%	8.75%	10.99%	10.43%
Neck	62.90%	51.25%	49.45%	80.00%
Right Shoulder	46.77%	41.25%	45.05%	42.61%
Left Shoulder	45.16%	43.75%	45.05%	40.87%
Upper Back	40.32%	50.00%	65.93%	41.74%
Right Upper Arm	37.10%	42.50%	38.46%	36.52%
Left Upper Arm	22.58%	27.50%	25.27%	24.35%
Lower Back	51.61%	61.25%	45.05%	45.22%
Right Elbow	19.35%	5.00%	17.58%	12.17%
Left Elbow	11.29%	10.00%	16.48%	11.30%
Right Forearm	25.81%	32.50%	26.37%	32.17%
Left Forearm	30.65%	32.50%	28.57%	41.74%
Right Wrist	40.32%	37.50%	36.26%	20.00%
Left Wrist	35.48%	47.50%	43.96%	26.09%
Hips/Buttocks	3.23%	2.50%	7.69%	6.09%
Right Thigh	3.23%	1.25%	2.20%	1.74%
Left Thigh	6.45%	1.25%	6.59%	1.74%
Right Knee	6.45%	1.25%	6.59%	1.74%
Left Knee	1.61%	5.00%	5.49%	3.48%
Right Lower Leg	0.00%	1.25%	3.30%	0.00%
Left Lower Leg	0.00%	2.50%	5.49%	0.00%
Right Foot/Ankle	6.45%	3.75%	4.40%	5.22%
Left Foot/Ankle	0.00%	5.00%	6.59%	2.61%
Right Thumb	30.65%	36.25%	32.97%	38.26%
Left Thumb	29.03%	36.25%	30.77%	31.30%
Right Index Finger	20.97%	11.25%	21.98%	12.17%
Left Index Finger	24.19%	18.75%	26.37%	17.39%
Right Middle Finger	12.90%	5.00%	16.48%	4.35%
Left Middle Finger	19.35%	13.75%	18.68%	13.91%
Right Ring Finger	8.06%	5.00%	9.89%	2.61%
Left Ring Finger	17.74%	16.25%	21.98%	13.04%
Right Pinkie	29.03%	10.00%	15.38%	9.57%
Left Pinkie	22.58%	21.25%	18.68%	19.13%
Right Palm	16.13%	11.25%	13.19%	6.96%
Left Palm	17.74%	22.50%	24.18%	8.70%
Right Bottom of Thumb	35.48%	32.50%	29.67%	27.83%
Left Bottom of Thumb	41.94%	40.00%	35.16%	39.13%

Table 5.14. The musical performance interference at total body and body parts according to the experience levels

Body Parts	Musical Performance Interference			
	≤5 Years	6-11 years	11-20 years	21+ years
Total Body	69.35%	66.25%	70.33%	60.87%
Ears	1.61%	3.75%	3.30%	2.61%
Face/Jaws	6.45%	7.50%	6.59%	5.22%
Mouth/Lips	3.23%	11.25%	3.30%	7.83%
Teeth	0.00%	2.50%	2.20%	1.74%
Neck	20.97%	13.75%	16.48%	26.96%
Right Shoulder	12.90%	6.25%	12.09%	16.52%
Left Shoulder	11.29%	11.25%	10.99%	12.17%
Upper Back	9.68%	13.75%	19.78%	10.43%
Right Upper Arm	16.13%	5.00%	8.79%	8.70%
Left Upper Arm	6.45%	6.25%	3.30%	5.22%
Lower Back	9.68%	15.00%	15.38%	17.39%
Right Elbow	9.68%	0.00%	3.30%	5.22%
Left Elbow	3.23%	0.00%	3.30%	4.35%
Right Forearm	9.68%	1.25%	6.59%	4.35%
Left Forearm	11.29%	3.75%	6.59%	9.57%
Right Wrist	16.13%	11.25%	13.19%	4.35%
Left Wrist	14.52%	13.75%	16.48%	8.70%
Hips/Buttocks	3.23%	0.00%	3.30%	2.61%
Right Thigh	3.23%	0.00%	1.10%	0.87%
Left Thigh	1.61%	0.00%	1.10%	0.00%
Right Knee	3.23%	1.25%	2.20%	0.00%
Left Knee	0.00%	2.50%	2.20%	0.00%
Right Lower Leg	0.00%	0.00%	1.10%	0.00%
Left Lower Leg	0.00%	0.00%	2.20%	0.00%
Right Foot/Ankle	3.23%	1.25%	1.10%	0.87%
Left Foot/Ankle	0.00%	1.25%	4.40%	0.87%
Right Thumb	11.29%	7.50%	9.89%	11.30%
Left Thumb	11.29%	12.50%	9.89%	7.83%
Right Index Finger	6.45%	0.00%	3.30%	2.61%
Left Index Finger	6.45%	0.00%	7.69%	5.22%
Right Middle Finger	1.61%	0.00%	3.30%	0.87%
Left Middle Finger	6.45%	0.00%	5.49%	4.35%
Right Ring Finger	1.61%	0.00%	3.30%	0.00%
Left Ring Finger	6.45%	0.00%	7.69%	4.35%
Right Pinkie	12.90%	1.25%	2.20%	1.74%
Left Pinkie	9.68%	2.50%	6.59%	6.09%
Right Palm	8.06%	0.00%	6.59%	2.61%
Left Palm	9.68%	3.75%	7.69%	2.61%
Right Bottom of Thumb	8.06%	5.00%	5.49%	5.22%
Left Bottom of Thumb	14.52%	8.75%	10.99%	9.57%

Table 5.15. The weighted scores of total body and body parts according to the first instrument groups

Body Parts	Weighted Scores					
	Brass	**Drums and Percussion**	**Keyboard**	**Plucked Strings**	**Strings**	**Woodwind**
Total Body	23.609	32.742	31.577	55.588	89.015	44.600
Ears	0.870	2.694	0.148	0.784	1.947	1.075
Face/Jaws	4.391	0.000	0.134	0.046	2.068	1.758
Mouth/Lips	10.587	0.000	0.063	0.268	0.000	2.958
Teeth	1.804	0.000	0.092	0.046	0.318	0.717
Neck	1.652	1.065	3.718	3.964	11.667	4.400
Right Shoulder	0.130	0.597	1.092	1.974	6.727	3.158
Left Shoulder	0.000	0.435	1.486	4.273	6.644	1.817
Upper Back	0.000	1.968	1.514	2.887	8.189	2.550
Right Upper Arm	0.130	0.258	0.352	1.335	3.379	1.500
Left Upper Arm	0.000	0.048	0.415	1.186	3.864	0.883
Lower Back	0.565	5.855	3.106	3.031	2.871	1.542
Right Elbow	0.000	0.000	0.275	0.412	3.962	0.492
Left Elbow	0.000	0.000	0.352	0.454	4.280	0.333
Right Forearm	0.000	0.903	1.014	1.325	1.674	0.950
Left Forearm	0.000	0.355	1.162	2.273	2.538	1.392
Right Wrist	0.435	4.355	0.993	1.180	4.265	2.950
Left Wrist	0.130	2.935	1.077	3.268	2.447	0.950
Hips/Buttocks	0.000	0.403	0.021	0.345	0.682	0.000
Right Thigh	0.000	0.000	0.000	0.155	0.091	0.000
Left Thigh	0.000	0.290	0.000	0.113	0.136	0.000
Right Knee	0.000	0.629	0.000	0.113	0.091	0.000
Left Knee	0.000	1.000	0.000	0.582	0.068	0.000
Right Lower Leg	0.000	0.339	0.000	0.062	0.000	0.000
Left Lower Leg	0.000	0.097	0.000	0.371	0.076	0.000
Right Foot/Ankle	0.000	1.113	0.000	0.335	0.682	0.000
Left Foot/Ankle	0.000	0.484	0.000	0.191	0.098	0.000
Right Thumb	0.000	2.435	2.310	0.789	3.636	2.200
Left Thumb	0.000	0.097	1.239	4.253	1.508	1.717
Right Index Finger	0.000	0.258	0.296	0.933	0.500	0.775
Left Index Finger	0.000	0.194	0.317	3.211	1.008	1.025
Right Middle Finger	0.000	0.000	0.246	0.258	0.402	0.150
Left Middle Finger	0.000	0.000	0.373	1.856	1.227	0.125
Right Ring Finger	0.000	0.000	0.106	0.134	0.500	1.225
Left Ring Finger	0.000	0.000	0.148	2.582	1.788	0.175
Right Pinkie	0.370	0.000	1.021	0.155	1.015	4.192
Left Pinkie	0.000	0.000	0.894	1.814	1.492	0.583
Right Palm	0.478	2.887	0.852	0.216	1.902	0.325
Left Palm	0.261	0.758	1.289	1.696	0.598	0.633
Right Bottom of Thumb	0.978	0.145	3.197	1.794	1.765	1.050
Left Bottom of Thumb	0.826	0.145	2.275	4.923	2.909	1.000

Table 5.16. The prevalence of discomfort at total body and body parts according to the first instrument groups

Body Parts	Prevalence					
	Brass	Drums and Percussion	Keyboard	Plucked Strings	Strings	Woodwind
Total Body	95.7%	100.0%	97.2%	99.0%	100.0%	96.7%
Ears	34.8%	67.7%	8.5%	7.2%	18.2%	38.3%
Face/Jaws	73.9%	0.0%	7.0%	3.1%	45.5%	60.0%
Mouth/Lips	91.3%	0.0%	4.2%	4.1%	0.0%	73.3%
Teeth	65.2%	0.0%	2.8%	2.1%	12.1%	11.7%
Neck	52.2%	45.2%	59.2%	58.8%	74.2%	71.7%
Right Shoulder	8.7%	9.7%	35.2%	44.3%	62.1%	63.3%
Left Shoulder	0.0%	9.7%	40.8%	58.8%	53.0%	45.0%
Upper Back	0.0%	51.6%	45.1%	48.5%	65.2%	58.3%
Right Upper Arm	8.7%	12.9%	15.5%	51.5%	57.6%	48.3%
Left Upper Arm	0.0%	3.2%	15.5%	30.9%	47.0%	23.3%
Lower Back	26.1%	80.6%	62.0%	47.4%	39.4%	45.0%
Right Elbow	0.0%	0.0%	7.0%	10.3%	34.8%	13.3%
Left Elbow	0.0%	0.0%	9.9%	10.3%	28.8%	11.7%
Right Forearm	0.0%	25.8%	23.9%	47.4%	31.8%	18.3%
Left Forearm	0.0%	16.1%	29.6%	51.5%	30.3%	38.3%
Right Wrist	8.7%	67.7%	15.5%	27.8%	45.5%	33.3%
Left Wrist	8.7%	61.3%	23.9%	52.6%	37.9%	26.7%
Hips/Buttocks	0.0%	19.4%	1.4%	9.3%	3.0%	0.0%
Right Thigh	0.0%	0.0%	0.0%	6.2%	1.5%	0.0%
Left Thigh	0.0%	19.4%	0.0%	4.1%	4.5%	0.0%
Right Knee	0.0%	19.4%	0.0%	4.1%	4.5%	0.0%
Left Knee	0.0%	12.9%	0.0%	7.2%	4.5%	0.0%
Right Lower Leg	0.0%	3.2%	0.0%	3.1%	0.0%	0.0%
Left Lower Leg	0.0%	3.2%	0.0%	4.1%	3.0%	0.0%
Right Foot/Ankle	0.0%	25.8%	0.0%	7.2%	3.0%	0.0%
Left Foot/Ankle	0.0%	19.4%	0.0%	5.2%	3.0%	0.0%
Right Thumb	0.0%	9.7%	42.3%	22.7%	47.0%	60.0%
Left Thumb	0.0%	6.5%	26.8%	37.1%	42.4%	43.3%
Right Index Finger	0.0%	12.9%	8.5%	18.6%	10.6%	35.0%
Left Index Finger	0.0%	9.7%	8.5%	27.8%	31.8%	28.3%
Right Middle Finger	0.0%	0.0%	7.0%	9.3%	18.2%	10.0%
Left Middle Finger	0.0%	0.0%	9.9%	26.8%	27.3%	8.3%
Right Ring Finger	0.0%	0.0%	5.6%	4.1%	9.1%	11.7%
Left Ring Finger	0.0%	0.0%	7.0%	27.8%	34.8%	6.7%
Right Pinkie	13.0%	0.0%	11.3%	8.2%	16.7%	35.0%
Left Pinkie	0.0%	0.0%	12.7%	39.2%	22.7%	13.3%
Right Palm	21.7%	25.8%	11.3%	6.2%	10.6%	8.3%
Left Palm	13.0%	12.9%	12.7%	19.6%	16.7%	25.0%
Right Bottom of Thumb	43.5%	9.7%	32.4%	35.1%	25.8%	33.3%
Left Bottom of Thumb	34.8%	9.7%	42.3%	53.6%	36.4%	30.0%

Table 5.17. The musical performance interference at total body and body parts according to the first instrument groups

Body Parts	Musical Performance Interference					
	Brass	Drums and Percussion	Keyboard	Plucked Strings	Strings	Woodwind
Total Body	39.13%	70.97%	57.75%	63.92%	80.30%	71.67%
Ears	0.0%	3.2%	1.4%	3.1%	3.0%	5.0%
Face/Jaws	17.4%	0.0%	0.0%	0.0%	9.1%	20.0%
Mouth/Lips	34.8%	0.0%	0.0%	2.1%	0.0%	21.7%
Teeth	8.7%	0.0%	0.0%	1.0%	0.0%	5.0%
Neck	0.0%	3.2%	15.5%	13.4%	40.9%	30.0%
Right Shoulder	0.0%	6.5%	5.6%	11.3%	22.7%	18.3%
Left Shoulder	0.0%	6.5%	9.9%	14.4%	18.2%	8.3%
Upper Back	0.0%	22.6%	11.3%	11.3%	22.7%	10.0%
Right Upper Arm	0.0%	0.0%	2.8%	11.3%	16.7%	13.3%
Left Upper Arm	0.0%	0.0%	5.6%	5.2%	13.6%	0.0%
Lower Back	0.0%	38.7%	16.9%	16.5%	10.6%	8.3%
Right Elbow	0.0%	0.0%	0.0%	3.1%	15.2%	3.3%
Left Elbow	0.0%	0.0%	1.4%	1.0%	9.1%	3.3%
Right Forearm	0.0%	3.2%	2.8%	4.1%	6.1%	11.7%
Left Forearm	0.0%	3.2%	5.6%	11.3%	7.6%	10.0%
Right Wrist	4.3%	32.3%	2.8%	7.2%	13.6%	11.7%
Left Wrist	0.0%	29.0%	5.6%	20.6%	13.6%	5.0%
Hips/Buttocks	0.0%	0.0%	0.0%	7.2%	1.5%	0.0%
Right Thigh	0.0%	0.0%	0.0%	3.1%	1.5%	0.0%
Left Thigh	0.0%	0.0%	0.0%	1.0%	1.5%	0.0%
Right Knee	0.0%	9.7%	0.0%	1.0%	1.5%	0.0%
Left Knee	0.0%	6.5%	0.0%	2.1%	0.0%	0.0%
Right Lower Leg	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%
Left Lower Leg	0.0%	3.2%	0.0%	1.0%	0.0%	0.0%
Right Foot/Ankle	0.0%	6.5%	0.0%	2.1%	1.5%	0.0%
Left Foot/Ankle	0.0%	9.7%	0.0%	3.1%	0.0%	0.0%
Right Thumb	0.0%	6.5%	8.5%	3.1%	12.1%	26.7%
Left Thumb	0.0%	0.0%	9.9%	10.3%	10.6%	18.3%
Right Index Finger	0.0%	0.0%	1.4%	5.2%	4.5%	1.7%
Left Index Finger	0.0%	0.0%	1.4%	6.2%	7.6%	8.3%
Right Middle Finger	0.0%	0.0%	1.4%	3.1%	1.5%	0.0%
Left Middle Finger	0.0%	0.0%	2.8%	8.2%	6.1%	0.0%
Right Ring Finger	0.0%	0.0%	1.4%	2.1%	1.5%	0.0%
Left Ring Finger	0.0%	0.0%	1.4%	9.3%	9.1%	0.0%
Right Pinkie	0.0%	0.0%	2.8%	2.1%	4.5%	10.0%
Left Pinkie	0.0%	0.0%	4.2%	9.3%	7.6%	6.7%
Right Palm	0.0%	6.5%	5.6%	2.1%	3.0%	6.7%
Left Palm	0.0%	3.2%	5.6%	8.2%	3.0%	6.7%
Right Bottom of Thumb	0.0%	0.0%	11.3%	4.1%	3.0%	10.0%
Left Bottom of Thumb	0.0%	0.0%	9.9%	17.5%	10.6%	10.0%

5.1.3. Multicollinearity Check of the Independent Variables

The continuous independent variables were checked for a possible multicollinearity between them. A matrix plot was formed and spearmen correlation coefficients were calculated. The scatter plots of the continuous independent variables can be seen in Figure 5.7 and the correlation coefficients with p-values are shown in Table 5.18.

According to the matrix plot and correlation coefficients, a high correlation between age and experience can be seen. The Spearman correlation coefficient between age and experience were found to be 0.82 with a p-value of 0, which shows a significant and strong correlation. Thus, experience was used in the further analyses instead of age. Moreover, for music instrument playing, experience is a better indicator instead of age since a person can start playing any instrument at any age and instrument playing skills depend on the total time spent playing the instrument. There were some other significant correlations between the independent variables, however, they didn't have strong correlation coefficients and weren't removed from further analyses.

5.1.4. Categorization of the Variables

The variable experience was categorized in order to use in ANOVA, and daily stress and musical performance stress variables were categorized to use in Logistic Regression. The categorization of the variables is shown in Table 5.19.

5.1.5. Parametric and Non-Parametric ANOVA

For the group comparisons and the correlation analysis, parametric and non-parametric ANOVA tests were applied to investigate the effects of the variables. When the parametric ANOVA assumptions were not satisfied, log(Y), sqrt(Y), and 1/Y transformations were applied separately. If the ANOVA assumptions weren't satisfied yet even after the transformations, the output data were ranked and ANOVA was applied for ranked data. The satisfied assumptions after transformations were stated in this section while the unsatisfied assumptions of ANOVA were shown in Appendix D section.

The factors gender, experience and first musical instrument group effects were analyzed. ANOVA was applied to these factors while taking the outcome as total body, ears, neck, right & left shoulder, and upper and lower back weighted scores as investigated in Section 5.1.3. Moreover, in order to investigate all the instrument types' weighted score differences, the mostly affected body regions' weighted scores for each instrument type were added to the analysis. The added weighted scores were right and left thumb, right and left bottom of thumb, right and left wrist, right palm, mouth/lips, face/jaws, teeth, left elbow, and right pinkie. Since the number of instruments played by females and males were different, ANOVA was applied for male and female gender separately taking the factors as first instruments group and experience level.

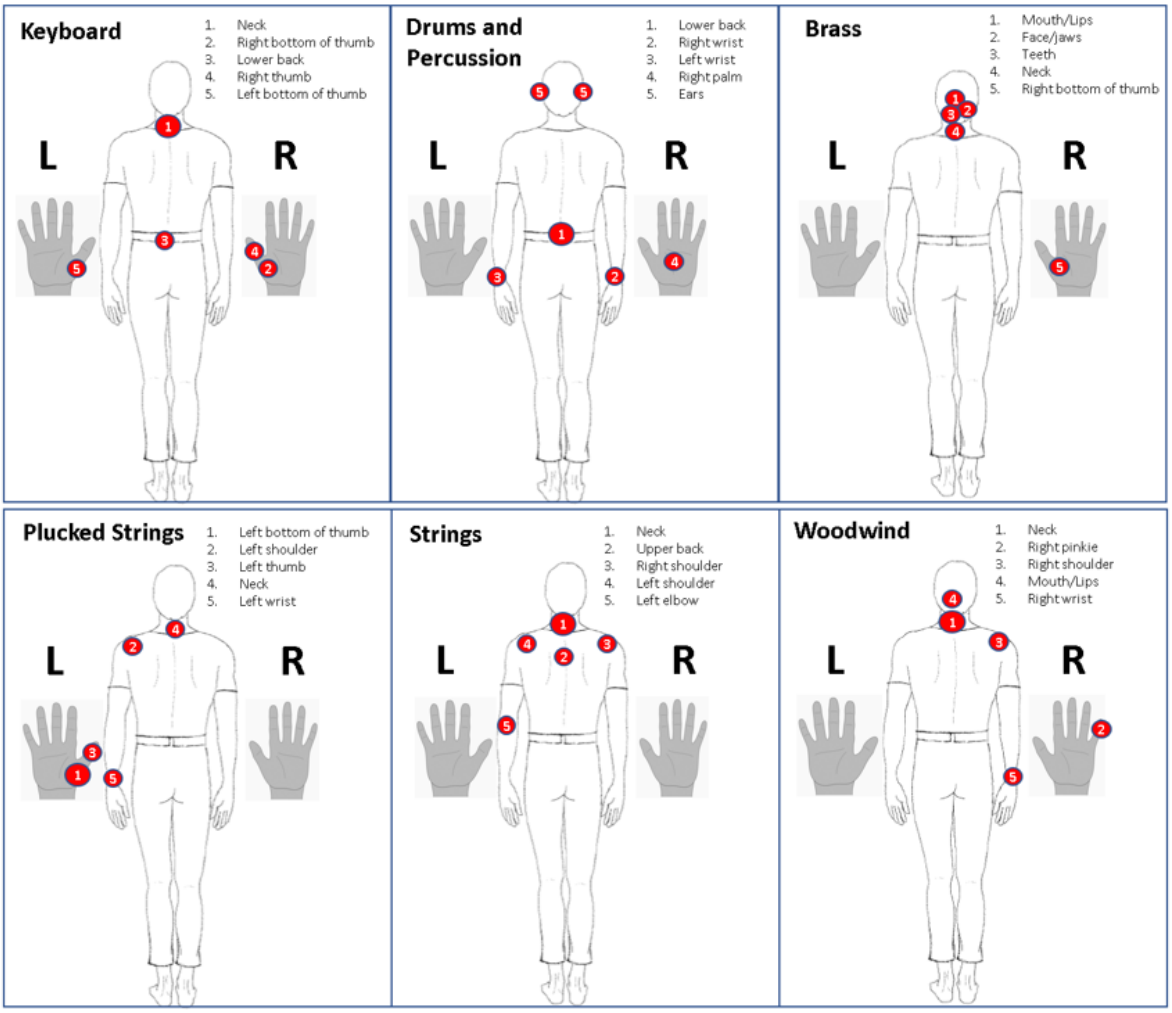


Figure 5.2. The most affected five body regions by musical instrument playing related symptoms for each instrument type

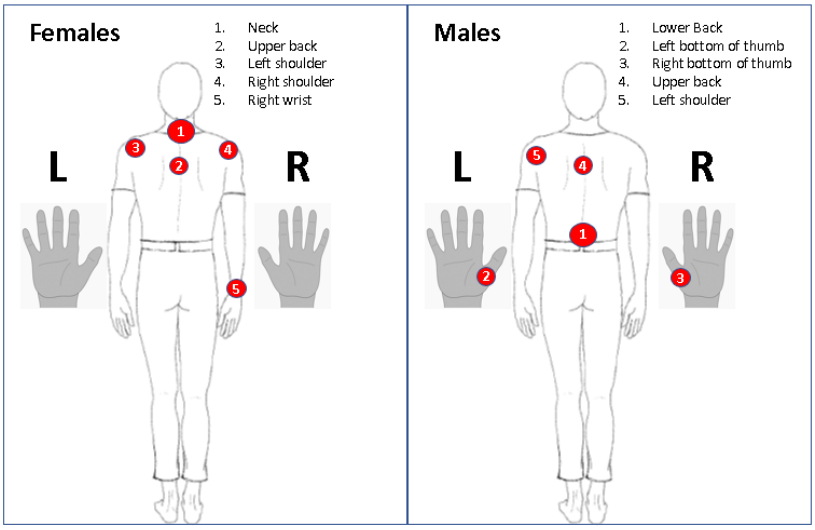


Figure 5.3. The most affected five body parts according to the gender

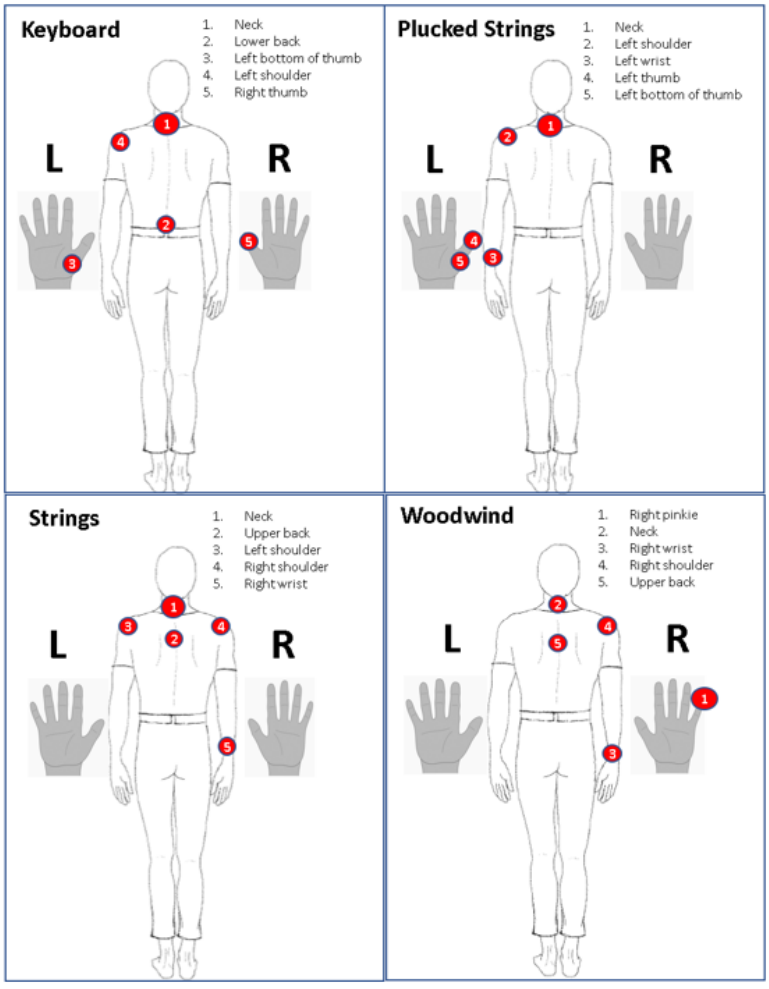


Figure 5.4. The most affected five body parts of female participants according to the first instrument groups

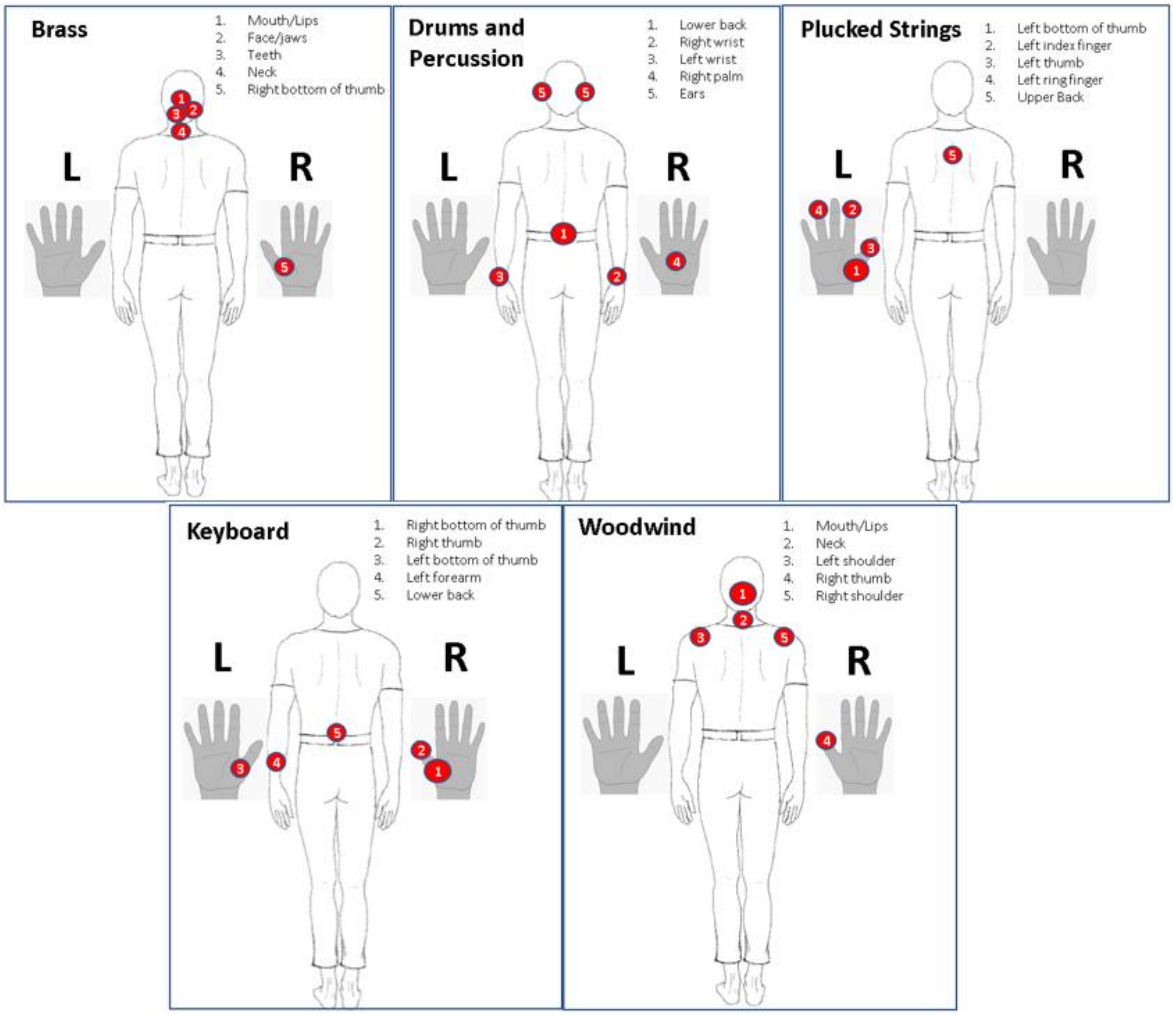


Figure 5.5. The most affected five body parts of male participants according to the first instrument groups

ANOVA for body part weighted scores were applied and after the important factors were found out, post-hoc analysis was made by using Bonferroni pairwise comparisons. For the interaction effects which were found to be important, interaction plot was used to show the first instrument type and experience interactions.

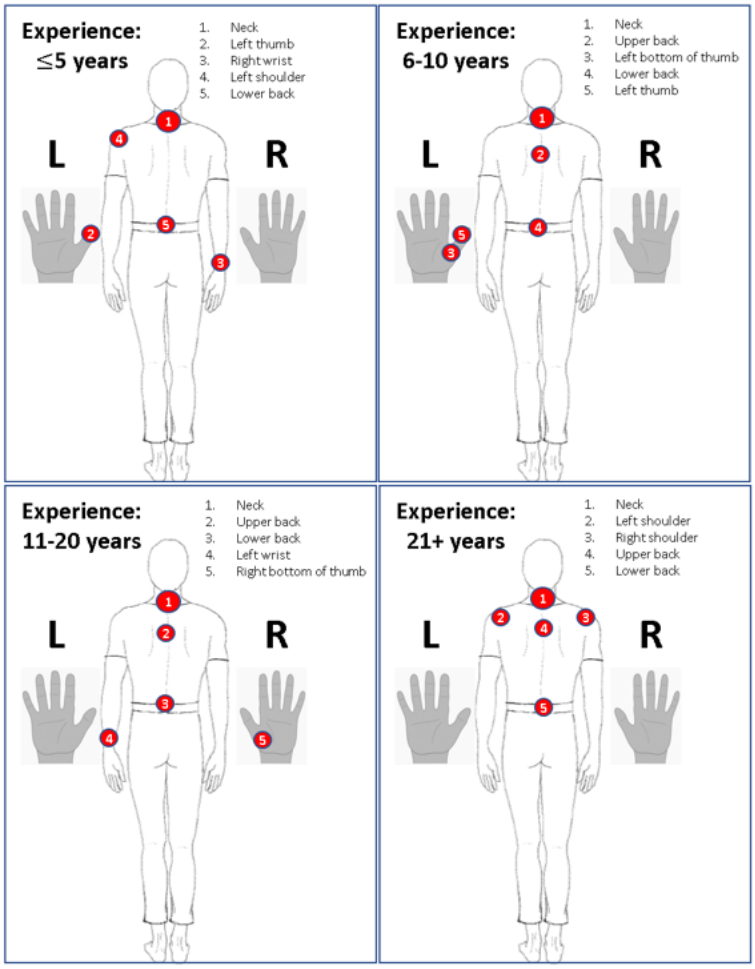


Figure 5.6. The most affected five body parts of participants according to the experience levels

5.1.5.1. Total Body Weighted Score and Females. The ANOVA test results of total body weighted scores for females are given in Table 5.20. After log(Y) transformation was applied, Anderson-Darling p-value of 0.726 and Bartlett's test result of 0.082 were obtained. The satisfied ANOVA assumptions are shown in Figure 5.8 while the unsatisfied assumptions and Levene's test results for the ANOVA made before transformation are shown in Figure D.1. and Table D.1. respectively. The important factor affecting females' total body weighted score was found out to be the first instrument group. According to the Bonferroni pairwise comparisons in Table 5.21, the strings players' weighted scores were found to be significantly larger than all the instrument groups except woodwind players. Moreover, woodwind players' weighted scores were found out to be significantly greater than keyboard players' weighted scores. According to the results of the analysis, the total

body weighted scores can be stated as $TBWS_{Strings}$ > $TBWS_{Woodwind}$ > $TBWS_{Plucked\ Strings}$ > $TBWS_{Keyboard}$.

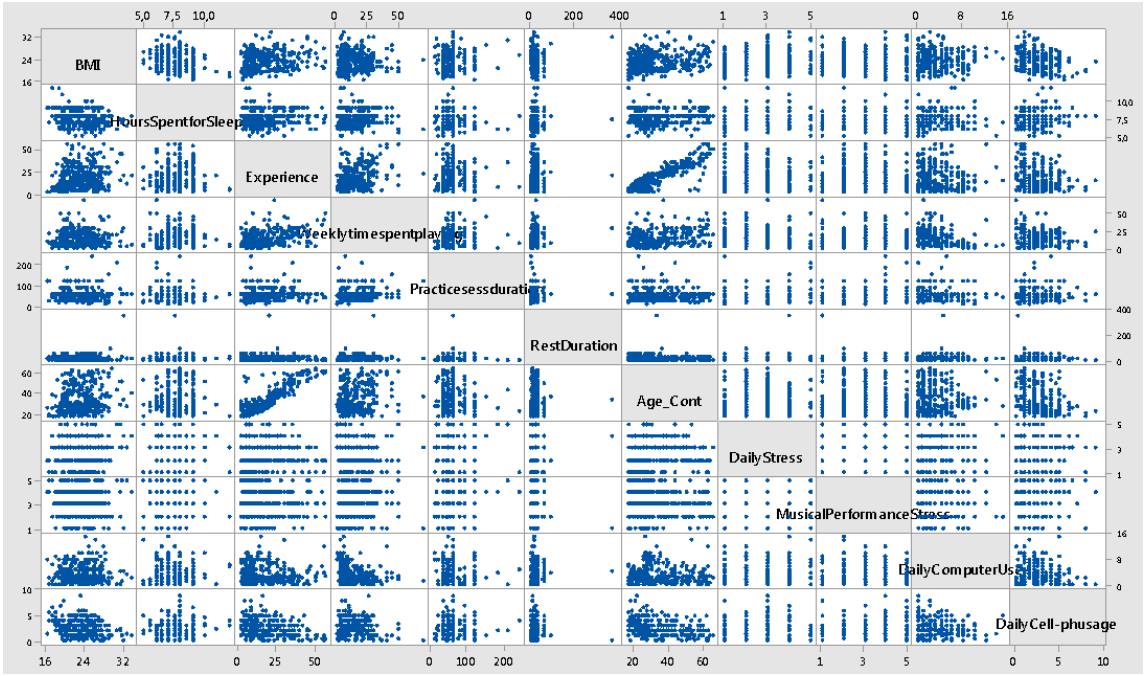


Figure 5.7. The scatter plots of the continuous variables

5.1.5.2. Total Body Weighted Score and Males. The results of the ANOVA for total body weighted scores of males are given in Table 5.22. In order to satisfy assumptions of ANOVA, log(Y) transformation was applied. An Anderson-Darling p-value of <0.005 and Levene's test result of 0.152 were obtained. However, since there was a slight deviation from normality, the normality assumption was considered as satisfied. The satisfied ANOVA assumptions are shown in Figure 5.9 while the unsatisfied ANOVA assumptions and Levene's test results are shown in Figure D.2 and Table D.2, respectively. No factor among first instrument groups and experience was found to be affecting the total body weighted score of males, thus, the Bonferroni pairwise comparisons were not applied.

Table 5.18. The correlation coefficients of continuous independent variables

Independent Continuous Variables	BMI	Hours Spent for Sleeping	Experience	Weekly Time Spent Playing	Practice Session Duration	Rest Duration	Age	Daily Stress	Musical Performance Stress	Daily Computer Use
Hours Spent for Sleeping	**-0.18***									
	<0.001**									
Experience	**0.18**	0.01								
	<0.001	0.81								
Weekly Time Spent Playing	0.01	**0.13**	**0.36**							
	0.84	**0.01**	**<0.001**							
Practice Session Duration	0.06	-0.07	**0.11**	**0.19**						
	0.28	0.17	**0.05**	**<0.001**						
Rest Duration	-0.03	**0.10**	-0.02	**0.23**	**0.30**					
	0.60	**0.05**	0.79	**<0.001**	**<0.001**					
Age	**0.19**	-0.02	**0.82**	**0.19**	0.05	-0.01				
	<0.001	0.73	**<0.001**	**<0.001**	0.39	0.91				
Daily Stress	-0.01	**-0.18**	-0.02	**-0.23**	0.05	-0.05	0.03			
	0.82	**<0.001**	0.68	**<0.001**	0.36	0.34	0.57			
Musical Performance Stress	-0.06	0.01	**-0.12**	-0.01	-0.03	-0.01	**-0.11**	**0.26**		
	0.27	0.90	**0.02**	0.87	0.63	0.86	**0.04**	**<0.001**		
Daily Computer Use	0.02	0.00	**-0.19**	**-0.40**	-0.10	-0.07	-0.03	0.07	-0.07	
	0.74	0.95	**0.00**	**<0.001**	0.07	0.21	0.58	0.18	0.17	
Daily Cell Phone Use	**-0.11**	**0.12**	**-0.31**	-0.09	-0.07	0.08	**-0.37**	-0.02	0.07	-0.08
	0.05	**0.03**	**0.00**	0.09	0.22	0.15	**<0.001**	0.68	0.19	0.12

*,** Spearman Corr. and p-value, respectively

Table 5.19. The categorization of the variables for statistical analyses

Variable	Mean	Factor 1	Factor 2	Factor 3	Factor 4
Experience (yrs)	17.38	**≤ 5**	**6-10**	**11-20**	**≥21**
Daily Stress (1 to 5)	2.69	**< 3**	**≥3**	-	-
Musical Performance Stress (1 to 5)	3.09	**≤ 3**	**> 3**	-	-

Table 5.20. The results of ANOVA for total body weighted scores of females

Total Body Weighted Scores of Females	Df	Adj SS	Adj MS	F-value	P-value
First Instrument Gr.	3	3.259	1.086	6.14	0.001*
Experience	3	0.668	0.223	1.26	0.290
First Instrument Gr * Experience	9	1.153	1.128	0.128	0.686
Error	151	0.177			

Table 5.21. The results of Bonferroni pairwise comparisons for TBWS of females

P-values	Keyboard	Plucked Strings	Strings
Plucked Strings	0.177	-	-
Strings	<0.001*	0.004*	-
Woodwind	0.035*	0.153	0.035*
Grouping			
First Instrument Gr.	**N**	**Mean**	**Group**
Strings	48	1.733	A
Woodwind	40	1.5428	A B
Plucked Strings	38	1.478	B
Keyboard	41	1.337	B

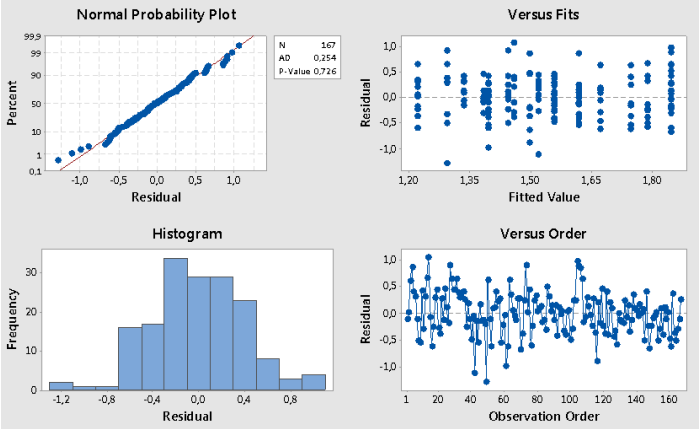


Figure 5.8. The ANOVA assumptions for TBWS of females

Table 5.22. The ANOVA results for total body weighted scores of males

Total Body Weighted Scores of Males	Df	Adj SS	Adj MS	F-value	P-value
First Instrument Gr.	5	1.730	0.346	1.42	0.221
Experience	3	0.483	0.482	0.66	0.579
First Instrument Gr * Experience	15	0.209	3.127	0.85	0.617
Error	157	38.351	0.244		

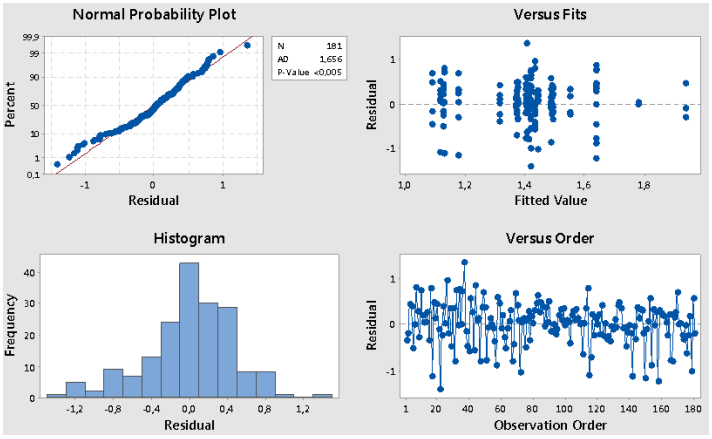


Figure 5.9. The ANOVA assumptions for TBWS of males

5.1.5.3. Ears Weighted Score and Females. The results of the ANOVA for ears weighted scores of females are given in Table 5.15. The ANOVA assumptions were not satisfied even after log(Y), sqrt(Y) and 1/Y transformations, so ANOVA was applied on ranked data. The unsatisfied ANOVA assumptions and Levene's test results are shown in Figure D.3 and Table D.3, respectively. The first instrument group and the interaction of experience and first instrument group were found out to be an important factor for females' ears weighted scores. According to the results of Bonferroni pairwise comparisons shown in Table 5.16, the strings instrument players had the highest and significantly different ears weighted scores from other instruments, and the the interaction plot in Figure 5.10 shows that the weighted scores of woodwind players with the experience levels of 21 or more years and 11-20 years had the highest weighted scores and followed by the strings players having 21 or more years of experience.

Table 5.23. ANOVA results for ears weighted scores of females

Ears Weighted Scores of Females	**Df**	**Adj SS**	**Adj MS**	**F-value**	**P-value**
First Instrument Gr.	3	23208	7736	10.53	<0.001*
Experience	3	3800	1266.7	1.72	0.164
First Instrument Gr * Experience	9	14750	1638.9	2.23	0.023*
Error	151	110908	734.5		

Table 5.24. The Bonferonni pairwise comparison results for ears weighted scores of females according to the first instrument groups

P-values	**Keyboard**	**Plucked Strings**	**Strings**
Plucked Strings	1.000	-	-
Strings	0.227	0.073	-
Woodwind	<0.001*	<0.001*	0.054
Grouping	**N**	**Mean**	**Group**
Woodwind	40	101.959	A
Strings	48	85.947	A B
Keyboard	41	73.232	B
Plucked Strings	38	70.500	B

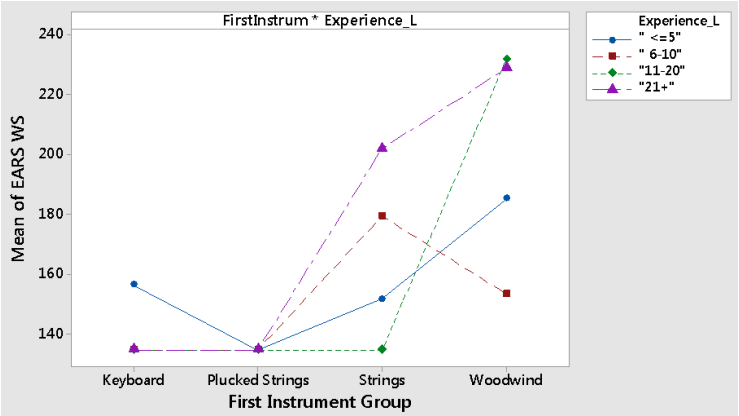


Figure 5.10.The interaction plot for ears weighted scores of females

5.1.5.4. Ears Weighted Score and Males. The results of the ANOVA for ears weighted scores of males are given in Table 5.25. Since the ANOVA assumptions were not satisfied even after log(Y), sqrt(Y) and 1/Y transformations, ANOVA was applied on ranked data. The unsatisfied ANOVA assumptions and Levene's test results are shown in Figure D.4 and Table D.4, respectively. The main effects of first instrument group, experience level and interaction of these two factors were found to have a significant effect on the weighted score of the ears for males. According to the Bonferroni pairwise comparison results of the first instrument groups shown in Table 5.26, the weighted scores of the drums and percussion players were found to be significantly higher from all instrument groups except woodwind players. The Bonferroni pairwise comparisons for experience levels shown in Table 5.27 explain that the ears weighted scores of the musicians having 21 or more years of experience was significantly higher weighted scores at ears that the other musicians.

Furthermore, the interaction effect plot in Figure 5.11 shows that the woodwind players having 21 or more years of experience had the highest weighted scores and followed by drums and percussion players having 6-10 and 21 or more years of experience.

Table 5.25. ANOVA results for ears weighted scores of males

Ears Weighted Scores of Males	**Df**	**Adj SS**	**Adj MS**	**F-value**	**P-value**
First Instrument Gr.	5	62370	12474	10.63	<0.001*
Experience	3	30808	10269	8.75	<0.001*
First Instrument Gr * Experience	15	35711	2381	2.03	0.016*
Error	157	184242	1174		

Table 5.26. The Bonferroni pairwise comparison results for ears weighted scores of males according to the first instrument groups

	Brass	**Drums and Perc.**	**Keyboard**	**Plucked Strings**	**Strings**
Drums and Perc.	0.002*	-	-	-	-
Keyboard	1.000	< 0.001*	-	-	-
Plucked Strings	1.000	< 0.001*	1.000	-	-
Strings	1.000	< 0.001*	1.000	1.000	-
Woodwind	1.000	0.311	0.099	0.032*	0.543

Grouping	**N**	**Mean**	**Group**
Drums and Percussion	31	129.341	A
Woodwind	20	105.150	A B
Brass	23	89.575	B C
Strings	18	80.583	B C
Keyboard	30	76.561	B C
Plucked Strings	59	76.445	C

Table 5.27. The Bonferroni pairwise comparison results for ears weighted scores of males according to the experience levels

	Less than or equal to 5 years	**11-20 years**	**21+ years**
11-20 years	1.000	-	-
21+ years	< 0.001*	0.001*	-
6-10 years	0.720	1.000	0.005*

Grouping	**N**	**Mean**	**Group**
21+ years	54	117.850	A
11-20 years	42	90.180	B
6-10 years	54	87.261	B
Less than or equal to 5 years	31	76.479	B

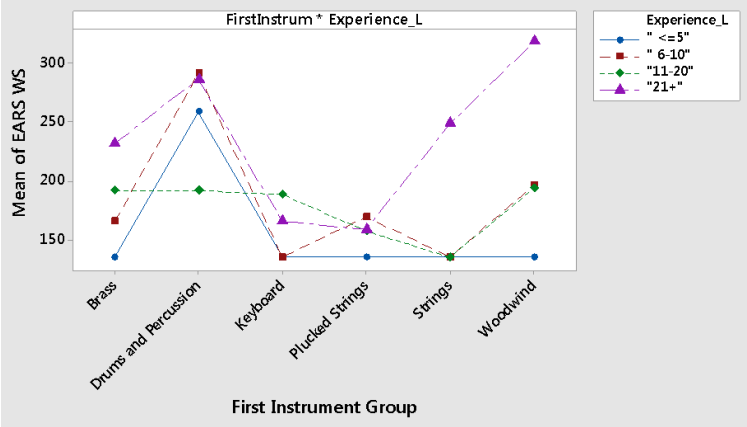


Figure 5.11. The interaction plot of ears weighted scores of males

5.1.5.5. Neck Weighted Score and Females. The results of the ANOVA for neck weighted scores of females are given in Table 5.28. In order to satisfy the assumptions of ANOVA, log(Y) transformation was applied and Anderson-Darling p-value of 0.141 and Bartlett's test p-value 0.065 were obtained. The satisfied ANOVA assumptions are shown in Figure 5.12 and the unsatisfied assumptions and Levene's test results for the ANOVA made before transformation are shown in Figure D.5 and Table D.5, respectively. ANOVA results show that experience had a significant effect on the neck weighted score of females. It can be concluded from Bonferroni pairwise comparisons shown in Table 5.29, musicians having 21 or more years of experience had significantly larger weighted scores at their necks than the other musicians except musicians having 5 or less years of experience.

Table 5.28. ANOVA results for neck weighted scores of females

Neck Weighted Scores of Females	**Df**	**Adj SS**	**Adj MS**	**F-value**	**P-value**
First Instrument Gr.	3	4.244	1.415	1.09	0.355
Experience	3	16.098	5.366	4.13	0.008*
First Instrument Gr * Experience	9	9.405	1.045	0.80	0.612
Error	151	196.056	1.298		

Table 5.29. The Bonferroni pairwise comparison results for neck weighted scores of females according to the experience levels

	Less than or equal to 5 years	**11-20 years**	**21+ years**
11-20 years	1.000	-	-
21+ years	0.991	0.028*	-
6-10 years	1.000	1.000	0.020*
Grouping	**N**	**Mean**	**Group**
21+ years	61	1.850	A
Less than or equal to 5 years	31	1.496	A B
11-20 years	37	1.158	B
6-10 years	38	1.143	B

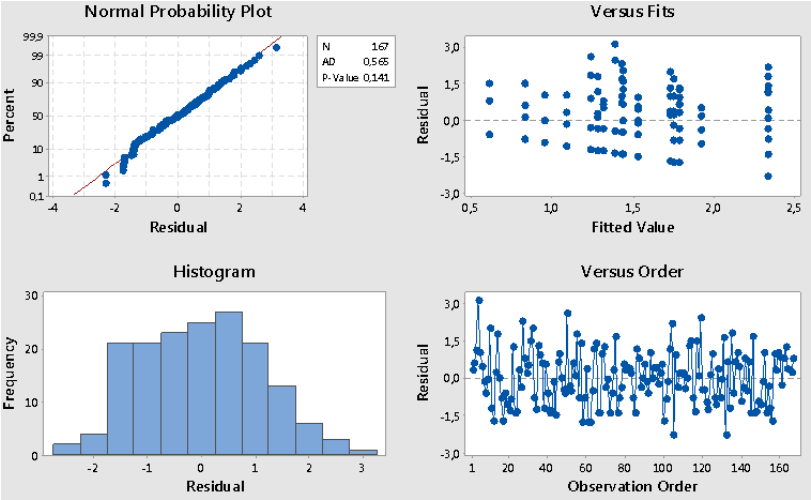


Figure 5.12. The ANOVA assumptions for neck weighted scores of females

5.1.5.6. Neck Weighted Score and Males. The results of ANOVA for neck weighted scores of males are given in Table 5.30. ANOVA assumptions were not satisfied even after applying log(Y), sqrt(Y), and 1/Y transformations, thus, ANOVA was applied on the ranked data. The unsatisfied ANOVA assumptions and Levene's test results are shown in Figure D.6 and Table D.6, respectively. The results of the ANOVA show that the first instrument group had a significant effect on neck weighted scores of males. Bonferroni pairwise comparison results illustrated in Table 5.31 show that strings instruments had the highest weighted scores which were significantly larger than the weighted scores of plucked strings and drums and percussion instrument family.

Table 5.30. ANOVA results for neck weighted scores of males

Neck Weighted Scores of Males	Df	Adj SS	Adj MS	F-value	P-value
First Instrument Gr.	5	39207	7841	3.57	0.004*
Experience	3	10756	3585	1.63	0.184
First Instrument Gr * Experience	15	33478	2232	1.02	0.442
Error	157	344986	2197		

Table 5.31. The Bonferroni pairwise comparison results for neck weighted scores of males according to the first instrument groups

	Brass	Drums and Perc.	Keyboard	Plucked Strings	Strings
Drums and Perc.	1.000	-	-	-	-
Keyboard	1.000	1.000	-	-	-
Plucked Strings	1.000	1.000	1.000	-	-
Strings	0.646	0.007*	0.100	0.015*	-
Woodwind	1.000	0.236	1.000	0.549	1.000

Grouping	N	Mean	Group	
Strings	18	126.903	A	
Woodwind	20	109.204	A	B
Brass	23	94.951	A	B
Keyboard	30	86.396	A	B
Plucked Strings	59	82.681		B
Drums and Perc.	31	74.614		B

5.1.5.7. Right Shoulder Weighted Score and Females. ANOVA results for the right shoulder weighted scores of females are shown in Table 5.32. ANOVA was applied on the ranked data since the assumptions were not satisfied at the beginning and after the log(Y), sqrt(Y), and 1/Y transformations. The unsatisfied ANOVA assumptions and Levene's test results are shown in Figure D.7 and Table D.7, respectively. No factor among the first instrument group and experience level was found as significant, thus, post-hoc analysis was not applied.

Table 5.32. ANOVA results for right shoulder weighted scores of females

Right Shoulder Weighted Scores of Females	Df	Adj SS	Adj MS	F-value	P-value
First Instrument Gr.	3	12935	4312	2.18	0.093
Experience	3	4079	1360	0.69	0.562
First Instrument Gr * Experience	9	26838	2982	1.51	0.151
Error	151	299185	1981		

5.1.5.8. Right Shoulder Weighted Score and Males. The results ANOVA for right shoulder weighted scores of males, which are shown in Table 5.33, show that the first instrument group was the important factor affecting right shoulder weighted score of males. Even

though the log(Y), sqrt(Y), and 1/Y transformations were applied, the ANOVA assumptions were not satisfied, hence the ANOVA was applied on the ranked data. The unsatisfied assumptions are shown in Figure D.8 and Table D.8, respectively. The results of the Bonferroni pairwise comparisons shown in Table 5.34 express that strings instrument group had significantly higher right shoulder weighted scores than other instruments except woodwind instrument group. Woodwind instruments had significantly higher right shoulder weighted scores than brass and drums and percussion instrument groups.

Table 5.33. ANOVA results for right shoulder weighted scores of males

Right Shoulder Weighted Scores of Males	**Df**	**Adj SS**	**Adj MS**	**F-value**	**P-value**
First Instrument Gr.	3	58493	11698.6	7.64	< 0.001*
Experience	3	1837	612.3	0.40	0.753
First Instrument Gr * Experience	15	32003	2133.5	1.39	0.157
Error	157	240544	1532.1		

Table 5.34. The results for Bonferroni pairwise comparisons of right shoulder weighted scores of males according to the first instrument groups

	Brass	**Drums and Perc.**	**Keyboard**	**Plucked Strings**	**Strings**
Drums and Perc.	1.000	-	-	-	-
Keyboard	1.000	1.000	-	-	-
Plucked Strings	0.256	0.120	1.000	-	-
Strings	< 0.001*	< 0.001*	0.012*	0.021*	-
Woodwind	0.005*	0.002*	0.291	0.616	1.000

Grouping	**N**	**Mean**	**Group**
Strings	18	130.356	A
Woodwind	20	116.188	A B
Plucked Strings	59	94.546	B C
Keyboard	30	88.160	B C
Drums and Perc.	31	69.870	C
Brass	23	69.829	C

5.1.5.9. Left Shoulder Weighted Score and Females. For the left shoulder weighted scores of females, the results of ANOVA are shown in Table 5.35. ANOVA was applied on the ranked data due to the unsatisfied assumptions. The unfulfilled assumptions are shown in Figure D.9 and Table D.9, respectively. The ANOVA results show that the interaction of the first instrument group and experience level was significant. According to the interaction plot shown in Figure 5.13, keyboard instrument group players having 5 or less years of experience had the highest left shoulder weighted scores, and they were followed by plucked strings and strings players having 21 or more years of experience, respectively.

Table 5.35. ANOVA results for left shoulder weighted scores of females

Left Shoulder Weighted Scores of Females	Df	Adj SS	Adj MS	F-value	P-value
First Instrument Gr.	3	9716	3238.7	1.69	0.172
Experience	3	1588	529.4	0.28	0.843
First Instrument Gr * Experience	9	37925	4213.8	2.19	0.025*
Error	151	289929	1920.1		

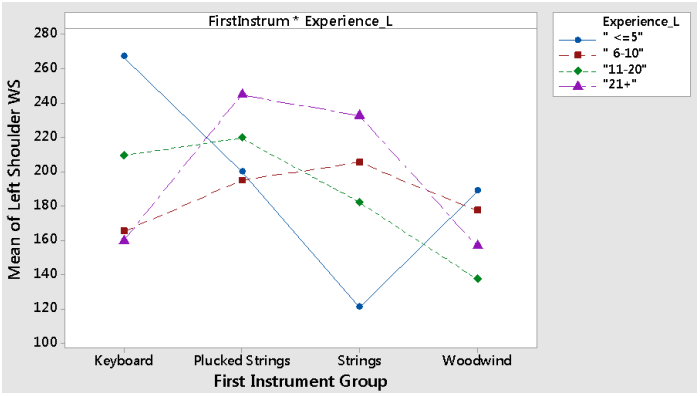


Figure 5.13. The interaction plot of female left shoulder weighted scores according to the first instrument groups and experience levels

5.1.5.10. Left Shoulder Weighted Score and Males. The results of ANOVA for left shoulder weighted scores of males, shown in Table 5.36, pointed out that first instrument group played an important role in music related musculoskeletal symptoms at male musicians' left shoulders. According to the results of Bonferroni pairwise comparisons shown in Table 5.37, strings instruments had the highest weighted scores among all instrument groups and the weighted scores of strings was significantly larger than keyboard, drums and percussion, and brass instrument groups. The ANOVA was applied on the ranked data since the assumptions were not satisfied after or before the log(Y), sqrt(Y) and 1/Y transformations. The unfulfilled assumptions are shown in Figure D.10 and Table D.10, respectively.

Table 5.36. ANOVA results for left shoulder weighted scores of males

Left Shoulder Weighted Scores of Males	Df	Adj SS	Adj MS	F-value	P-value
First Instrument Gr.	5	73037	14607.5	9.26	<0.001*
Experience	3	2843	947.6	0.60	0.615
First Instrument Gr * Experience	15	32921	2194.7	1.39	0.157
Error	157	247533	1576.6		

Table 5.37. The results for Bonferroni pairwise comparisons of left shoulder weighted scores of males according to the first instrument groups

	Brass	Drums and Perc.	Keyboard	Plucked Strings	Strings
Drums and Perc.	1.000	-	-	-	-
Keyboard	0.531	1.000	-	-	-
Plucked Strings	0.001*	0.002*	0.691	-	-
Strings	<0.001*	<0.001*	0.016*	0.626	-
Woodwind	0.001*	0.004*	0.343	1.000	1.000

Grouping	**N**	**Mean**	**Group**
Strings	18	126.277	A
Woodwind	20	112.225	A B
Plucked Strings	59	103.385	A B
Keyboard	30	84.558	B C
Drums and Perc.	31	67.086	C
Brass	23	59.500	C

5.1.5.11. Upper Back Weighted Score and Females. The results of ANOVA for upper back weighted scores of females, shown in Table 5.38, pointed out that the main effects and the interaction effect of first instrument group and the experience levels were significant. Since the ANOVA assumptions were not satisfied before and after the transformation application, ANOVA was applied on the ranked data. The unsatisfied assumptions are shown in Figure D.11 and Table D.11, respectively. According to the results of Bonferroni pairwise comparisons which are shown in Table 5.39, the female musicians playing instruments from strings instrument family were found to have significantly larger upper back weighted scores than keyboard and plucked strings instruments. The results of Bonferroni pairwise comparisons which are shown in Table 5.40 explain that female musicians having 11-20 years of experience had the largest weighted scores which were significantly different from the weighted scores of the musicians having 5 or less years of experience. The interaction plot shown in Figure 5.14 points out that the maximum weighted scores were at the strings players with 21 or more years of experience. Following the strings players, woodwind players with experience level between 11 and 20 years had the second largest weighted scores at upper back. The female musicians playing strings instruments and having 5 or less years of experience had the third largest upper back weighted scores.

Table 5.38. ANOVA results for upper back weighted scores of females

Upper Back Weighted Scores of Females	Df	Adj SS	Adj MS	F-value	P-value
First Instrument Gr.	3	37078	12359	7.26	<0.001*
Experience	3	21571	7190	4.22	0.007*
First Instrument Gr * Experience	9	37941	4216	2.48	0.012*
Error	151	257031	1702		

Table 5.39. The results for Bonferroni pairwise comparisons of upper back weighted scores of females according to the first instrument groups

P-values	Keyboard	Plucked Strings	Strings
Plucked Strings	1.000	-	-
Strings	0.010*	<0.001*	-
Woodwind	0.373	0.025*	1.000
Grouping			
First Instrument Gr.	**N**	**Mean**	**Group**
Strings	48	103.525	A
Woodwind	40	91.913	A B
Keyboard	41	73.981	B C
Plucked Strings	38	64.112	C

Table 5.40. The results for Bonferroni pairwise comparisons of upper back weighted scores of females according to the experience levels

	Less than or equal to 5 years	11-20 years	21+ years
11-20 years	0.009*	-	-
21+ years	0.595	0.279	-
6-10 years	0.039*	1.000	0.886
Grouping	**N**	**Mean**	**Group**
11-20 years	37	97.185	A
6-10 years	38	92.200	A B
21+ years	61	79.687	A B
Less than or equal to 5 years	31	64.458	B

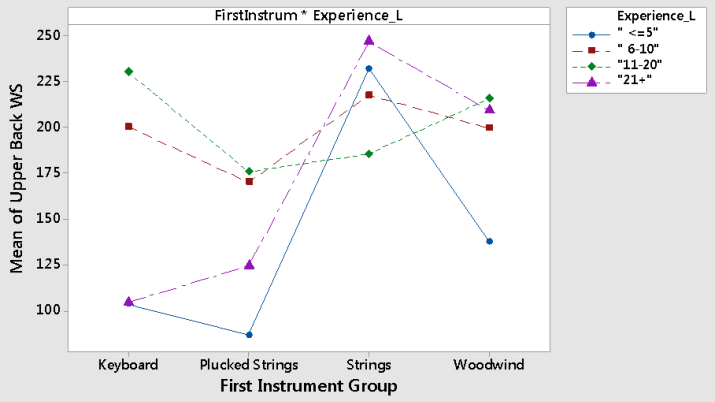


Figure 5.14. The interaction plot of female upper back weighted scores according to the first instrument groups and experience levels

5.1.5.12. Upper Back Weighted Score and Males. The results of ANOVA for upper back weighted scores of males, shown in Table 5.41, show that both first instrument group and experience levels were significant for upper back weighted scores of males. The results of Bonferroni pairwise comparisons for first instrument groups in Table 5.42 explain that all the male musicians playing instruments except brass instruments have upper back symptoms, however, the difference of the upper back weighted scores of each instrument was not significantly different except the difference between brass and other instrument groups. The ANOVA assumptions were considered to be satisfied after log(Y) transformation since there was a slight deviation from normality. The residuals' variance distribution was tested with Levene's test and a p-value of 0.129 was obtained. The ANOVA assumptions of this model is shown in Figure 5.15 while the unsatisfied ANOVA assumptions are shown Figure D.12 and Table D.12, respectively.

Table 5.41. ANOVA results for upper back weighted scores of males

Upper Back Weighted Scores of Males	**Df**	**Adj SS**	**Adj MS**	**F-value**	**P-value**
First Instrument Gr.	5	13.773	2.755	4.12	0.002*
Experience	3	3.771	1.257	1.88	0.135
First Instrument Gr * Experience	15	10.561	10.561	1.05	0.405
Error	157	105.019	0.668		

Table 5.42. The results for Bonferroni pairwise comparisons of upper back weighted scores of females according to the first instrument groups

	Brass	Drums and Perc.	Keyboard	Plucked Strings	Strings
Drums and Perc.	0.008*	-	-	-	-
Keyboard	0.038*	1.000	-	-	-
Plucked Strings	<0.001*	1.000	1.000	-	-
Strings	0.442	1.000	1.000	1.000	-
Woodwind	0.195	1.000	1.000	1.000	1.000

Grouping	**N**	**Mean**	**Group**	
Plucked Strings	59	0.941	A	
Drums and Perc.	31	0.854	A	
Keyboard	30	0.747	A	
Woodwind	20	0.665	A	B
Strings	18	0.600	A	B
Brass	23	0		B

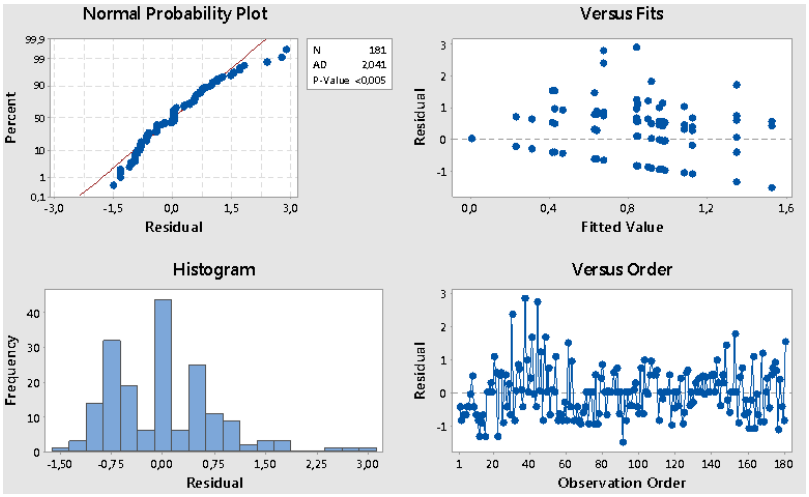


Figure 5.15. The ANOVA assumptions of upper back weighted scores of males

5.1.5.13. Lower Back Weighted Score and Females. ANOVA was applied for the ranked data because even after the log(Y), sqrt(Y), 1/Y transformations, the ANOVA assumptions couldn't be satisfied. The unsatisfied ANOVA assumptions are shown in Figure D.13 and Table D.13, respectively. For the lower back weighted scores of females, the results of the ANOVA are shown in Table 5.43. The results show that the interaction of experience levels and first instrument groups was significant for female lower back weighted scores. The interaction effect of the first instrument group and experience levels is shown in Figure 5.16, and it can be concluded that the musicians who had the highest weighted

scores were keyboard players with 21 or more and 11-20 years of experience, and strings players having 21 or more years of experience.

Table 5.43. ANOVA results for lower back weighted scores of females

Lower Back Weighted Scores of Females	Df	Adj SS	Adj MS	F-value	P-value
First Instrument Gr.	3	10999	3666	2.31	0.078
Experience	3	4958	1653	1.04	0.376
First Instrument Gr * Experience	9	74486	8276	5.22	<0.001*
Error	151	239433	1586		

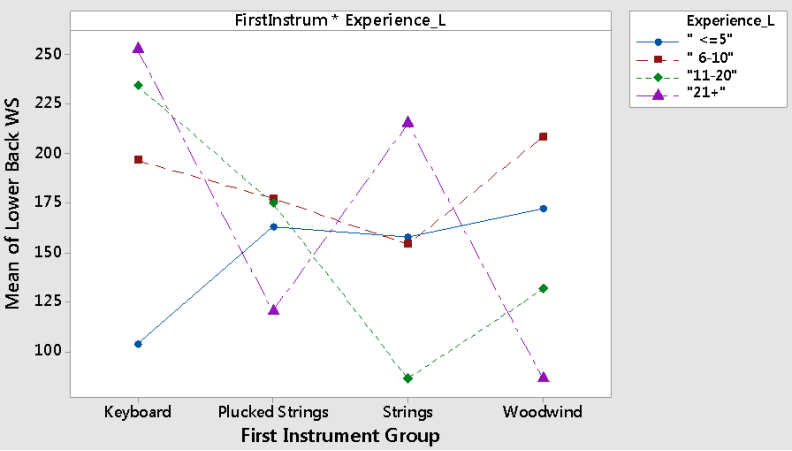


Figure 5.16. The interaction plot of female lower back weighted scores according to the first instrument groups and experience levels

5.1.5.14. Lower Back Weighted Score and Males. For the lower back weighted scores of males, the results of ANOVA, which are shown in Table 5.44, point out that the first instrument group had a significant effect on lower back weighted score of males. It can be concluded from the results of Bonferroni pairwise comparisons which are shown in Table 5.45, musicians playing drums and percussion instruments had significantly higher lower back weighted scores than other musical instrument groups except woodwind instrument family. The ANOVA model assumptions were considered to be satisfied after log(Y) transformation since there was a slight deviation from normality and residuals' variances were found to be equal with a Levene's test p-value of 0.493. The ANOVA assumptions for lower back weighted scores of males are shown in Figure 5.17 while the unfulfilled assumptions of ANOVA are shown in Figure D.14 and Table D.14, respectively.

Table 5.44. ANOVA results for lower back weighted scores of males

Lower Back Weighted Scores of Males	Df	Adj SS	Adj MS	F-value	P-value
First Instrument Gr.	5	19.753	3.951	4.96	<0.001*
Experience	3	0.731	0.243	0.31	0.821
First Instrument Gr * Experience	15	7.127	0.475	0.60	0.874
Error	157	125.033	0.796		

Table 5.45. The results for Bonferroni pairwise comparisons of lower back weighted scores of males according to the first instrument groups

	Brass	Drums and Perc.	Keyboard	Plucked Strings	Strings
Drums and Perc.	<0.001*	-	-	-	-
Keyboard	1.000	0.044*	-	-	-
Plucked Strings	0.373	0.029*	1.000	-	-
Strings	1.000	0.004*	1.000	1.000	-
Woodwind	0.773	0.332	1.000	1.000	1.000

Grouping	N	Mean	Group
Drums and Perc.	31	1.513	A
Woodwind	20	0.890	A B
Plucked Strings	59	0.852	B
Keyboard	30	0.774	B
Strings	18	0.748	B
Brass	23	0.323	B

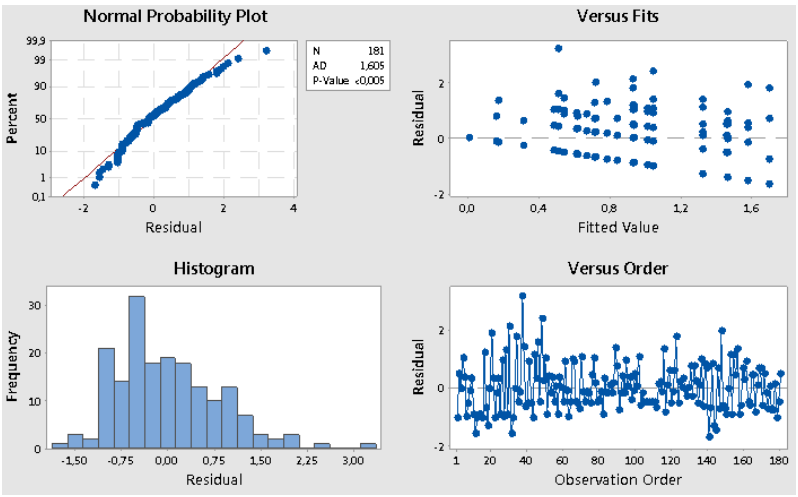


Figure 5.17. The ANOVA assumptions of lower back weighted scores of males

5.1.5.15. Right Bottom of Thumb Weighted Score and Females. The results of ANOVA, which are shown in Table 5.46, point out that none of the factors were significant for right thumb weighted scores. ANOVA was applied on the ranked data since the assumptions were not satisfied before and after the log(Y), sqrt(Y), and 1/Y transformations were

applied. The unfulfilled assumptions of ANOVA are shown in Figure D.15 and Table D.15, respectively.

Table 5.46. ANOVA results for right bottom of thumb weighted scores of females

Right Bottom of Thumb Weighted Scores of Females	**Df**	**Adj SS**	**Adj MS**	**F-value**	**P-value**
First Instrument Gr.	3	6884	2294.7	1.55	0.205
Experience	3	884	294.7	0.20	0.897
First Instrument Gr * Experience	9	23657	2628.6	1.77	0.078
Error	151	224253	1485.1		

5.1.5.16. Right Bottom of Thumb Weighted Score and Males. For the right bottom of thumb weighted scores of males, the results of ANOVA, which are shown in Table 5.47, point out that the first instrument group was a significant factor for the right bottom of thumb weighted scores of males. The results of Bonferroni pairwise comparisons shown in Table 5.48 explain that woodwind instruments have the highest weighted scores of right bottom of thumb weighted scores, however their weighted scores were only significantly larger than the drums and percussion group instruments. The weighted scores of right bottom of thumb are followed by keyboard, strings, brass and plucked strings instruments, respectively. Drums and percussion instruments had the lowest weighted scores. Since the assumptions of ANOVA were not satisfied before and after the application of log(Y), sqrt(Y), and 1/Y transformations, ANOVA was applied on the ranked data. The unfulfilled assumptions of ANOVA are shown in Figure D.16 and Table D.16, respectively

Table 5.47. ANOVA results for right bottom of thumb weighted scores of males

Right Bottom of Thumb Weighted Scores of Males	**Df**	**Adj SS**	**Adj MS**	**F-value**	**P-value**
First Instrument Gr.	5	26515	5302.9	2.79	0.019*
Experience	3	1152	384.1	0.20	0.895
First Instrument Gr * Experience	15	26152	1743.5	0.92	0.548
Error	157	298867	1903.6		

Table 5.48. The results of Bonferroni pairwise comparisons for right bottom of thumb weighted scores of males according to the first instrument groups

	Brass	Drums and Perc.	Keyboard	Plucked Strings	Strings
Drums and Perc.	0.490	-	-	-	-
Keyboard	1.000	0.047*	-	-	-
Plucked Strings	1.000	1.000	1.000	-	-
Strings	1.000	0.564	1.000	1.000	-
Woodwind	1.000	0.034*	1.000	0.904	1.000
Grouping	**N**	**Mean**	**Group**		
Woodwind	20	110.017	A		
Keyboard	30	104.853	A	B	
Strings	18	97.716	A	B	
Brass	23	96.924	A	B	
Plucked Strings	59	87.858	A	B	
Drums and Perc.	31	69.045		B	

5.1.5.17. Left Bottom of Thumb Weighted Score and Females. According to the results of ANOVA for the left bottom of thumb weighted scores of females, which are shown in Table 5.49, first instrument group was found to have a significant effect. The results of Bonferroni pairwise comparisons illustrated in Table 5.50 point out that plucked strings had the highest weighted scores among all instruments groups, however, they were only significantly greater than woodwind instruments. ANOVA was applied on the ranked data since the assumptions were not satisfied even the log(Y), sqrt(Y), and 1/Y transformations were applied. The unfulfilled assumptions of ANOVA are shown in Figure D.17 and Table D.17, respectively.

Table 5.49. ANOVA results for left bottom of thumb weighted scores of females

Left Bottom of Thumb Weighted Scores of Females	**Df**	**Adj SS**	**Adj MS**	**F-value**	**P-value**
First Instrument Gr.	3	15558	5186	3.10	0.029*
Experience	3	4416	1472	0.88	0.453
First Instrument Gr * Experience	9	14035	1559	0.93	0.499
Error	151	252458	1672		

Table 5.50. The results of Bonferroni pairwise comparisons for left bottom of thumb weighted scores of females according to the first instrument groups

P-values	**Keyboard**	**Plucked Strings**	**Strings**
Plucked Strings	1.000	-	-
Strings	1.000	0.283	-
Woodwind	0.648	0.020*	1.000
Grouping	**N**	**Mean**	**Group**
Plucked Strings	38	98.086	A
Keyboard	41	85.118	A B
Strings	48	79.733	A B
Woodwind	40	69.825	B

5.1.5.18. Left Bottom of Thumb Weighted Score and Males. The results of ANOVA for the left bottom of thumb weighted scores of males, which are shown in Table 5.51, first instrument group was found to have a significant effect. The results of Bonferroni pairwise comparisons illustrated in Table 5.52 point out that the plucked strings had the largest weighted scores, and together with woodwind instrument group, their weighted scores were significantly different from the weighted scores of drums and percussion instruments. Since the assumptions of ANOVA were not satisfied before and after the application of log(Y), sqrt(Y), and 1/Y transformations, ANOVA was applied on the ranked data. The unfulfilled assumptions of ANOVA are shown in Figure D.18 and Table D.18, respectively

Table 5.51. ANOVA results for left bottom of thumb weighted scores of males

Left Bottom of Thumb Weighted Scores of Males	**Df**	**Adj SS**	**Adj MS**	**F-value**	**P-value**
First Instrument Gr.	5	38617	7723.4	3.79	0.003*
Experience	3	2227	742.3	0.36	0.779
First Instrument Gr * Experience	15	20214	1347.6	0.66	0.819
Error	157	320083	2038.7		

Table 5.52. The result of Bonferroni pairwise comparisons for left bottom of thumb weighted scores of males according to the first instrument groups

	Brass	Drums and Perc.	Keyboard	Plucked Strings	Strings
Drums and Perc.	1.000	-	-	-	-
Keyboard	1.000	0.084	-	-	-
Plucked Strings	1.000	0.001*	1.000	-	-
Strings	1.000	0.354	1.000	1.000	-
Woodwind	1.000	0.044*	1.000	1.000	1.000
Grouping	**N**	**Mean**	**Group**		
Plucked Strings	59	105.386	A		
Woodwind	20	102.450	A		
Keyboard	30	95.966	A	B	
Strings	18	93.571	A	B	
Brass	23	85.854	A	B	
Drums and Perc.	31	61.232		B	

5.1.5.19. Right Thumb Weighted Score and Females. The results of ANOVA for the right thumb weighted scores of females are shown in Table 5.53. According to the results of ANOVA, main effect of first instrument group and the interaction effect of experience level and instrument group were found to be significant. It can be concluded from the Bonferroni pairwise comparison results in Table 5.54 that female plucked strings players had significantly smaller right thumb weighted scores than the other three instrument groups. Moreover, string players had the largest weighted scores among all instrument groups. The interaction effects shown in Figure 5.18 point out that for right thumb weighted scores, the female musicians playing woodwind instruments and having 11-20 years had the largest weighted scores and they were followed by the keyboard instrument group players who have 5 or smaller years of experience and woodwind and strings players having 21 or more years of experience. ANOVA was applied on the ranked data since the assumptions were not satisfied even after the log(Y), sqrt(Y), and 1/Y transformations were applied. The unfulfilled assumptions of ANOVA are shown in Figure D.19 and Table D.19, respectively.

Table 5.53. ANOVA results for right thumb weighted scores of females

Right Thumb Weighted Scores of Females	Df	Adj SS	Adj MS	F-value	P-value
First Instrument Gr.	3	33167	11056	6.22	0.001*
Experience	3	11995	3998	2.25	0.085
First Instrument Gr * Experience	9	48633	5404	3.04	0.002*
Error	151	268495	1778		

Table 5.54. The results of Bonferroni pairwise comparisons for right thumb weighted scores of females according to the first instrument groups

P-values	**Keyboard**	**Plucked Strings**	**Strings**
Plucked Strings	0.003*	-	-
Strings	1.000	0.030*	-
Woodwind	1.000	0.001*	1.000
Grouping	**N**	**Mean**	**Group**
Woodwind	40	96.163	A
Keyboard	41	93.161	A
Strings	48	85.249	A
Plucked Strings	38	58.252	B

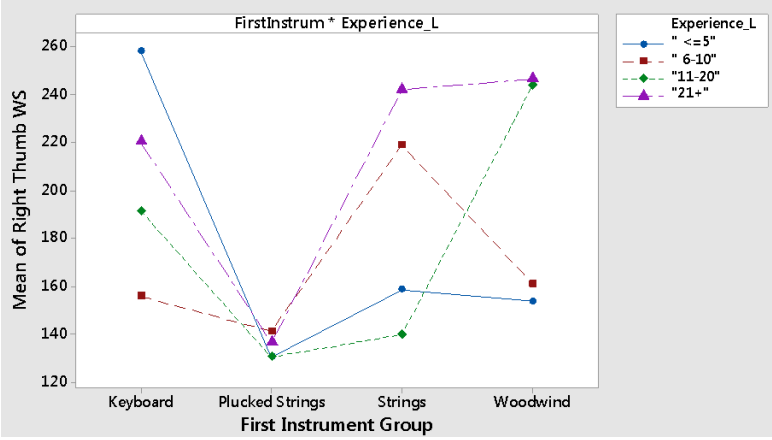


Figure 5.18. The interaction plot of female right thumb weighted scores

5.1.5.20. Right Thumb Weighted Score and Males. According to the results of ANOVA, which are shown in Table 5.55, the right thumb weighted scores of males are found to be significantly affected from the first instrument group. The results of Bonferroni comparisons shown in Table 5.56 explain that brass instruments had significantly smaller weighted scores than most of the instrument groups. Woodwind instrument group had significantly different weighted scores than the other instrument groups, and brass instrument group had significantly smaller weighted scores from woodwind and strings instruments. Since the assumptions of ANOVA were not satisfied before and after the application of log(Y), sqrt(Y), and 1/Y transformations, ANOVA was applied on the ranked data. The unfulfilled assumptions of ANOVA are shown in Figure D.20 and Table D.20, respectively.

Table 5.55. ANOVA results for right thumb weighted scores of males

Right Thumb Weighted Scores of Males	Df	Adj SS	Adj MS	F-value	P-value
First Instrument Gr.	5	51871	10374.3	6.93	<0.001*
Experience	3	5530	1843.2	1.23	0.300
First Instrument Gr * Experience	15	6094	406.3	0.27	0.997
Error	157	235129	1497.6		

Table 5.56. The results of Bonferroni pairwise comparisons for right thumb weighted scores of males according to the first instrument groups

	Brass	Drums and Perc.	Keyboard	Plucked Strings	Strings
Drums and Perc.	1.000	-	-	-	-
Keyboard	0.342	1.000	-	-	-
Plucked Strings	0.268	1.000	1.000	-	-
Strings	0.035*	0.210	1.000	1.000	-
Woodwind	<0.001*	<0.001*	0.018*	0.002*	0.880

Grouping	N	Mean	Group
Woodwind	20	131.096	A
Strings	18	106.080	A B
Keyboard	30	92.461	B C
Plucked Strings	59	90.257	B C
Drums and Perc.	31	75.948	B C
Brass	23	66.000	C

5.1.5.21. Left Thumb Weighted Score and Females. AVOVA results illustrated in Table 5.57 point out that the interaction effect of the first instrument group and the experience level of the left thumb weighted scores of females was significant. According to the interaction plot shown in Figure 5.19, the woodwind players having 21 or more years of experience had the highest weighted scores and they are followed by the woodwind players having 11-20 years of experience and plucked strings players having 5 years or less experience, respectively. ANOVA was applied on the ranked data since the assumptions were not satisfied even after the log(Y), sqrt(Y), and 1/Y transformations were applied. The unfulfilled assumptions of ANOVA are shown in Figure D.21 and Table D.21, respectively.

Table 5.57. ANOVA results for left thumb weighted scores of females

Left Thumb Weighted Scores of Females	Df	Adj SS	Adj MS	F-value	P-value
First Instrument Gr.	3	784	261.4	0.15	0.927
Experience	3	4186	1395.2	0.82	0.482
First Instrument Gr * Experience	9	44952	4994.7	2.95	0.003*
Error	151	255597	1692.7		

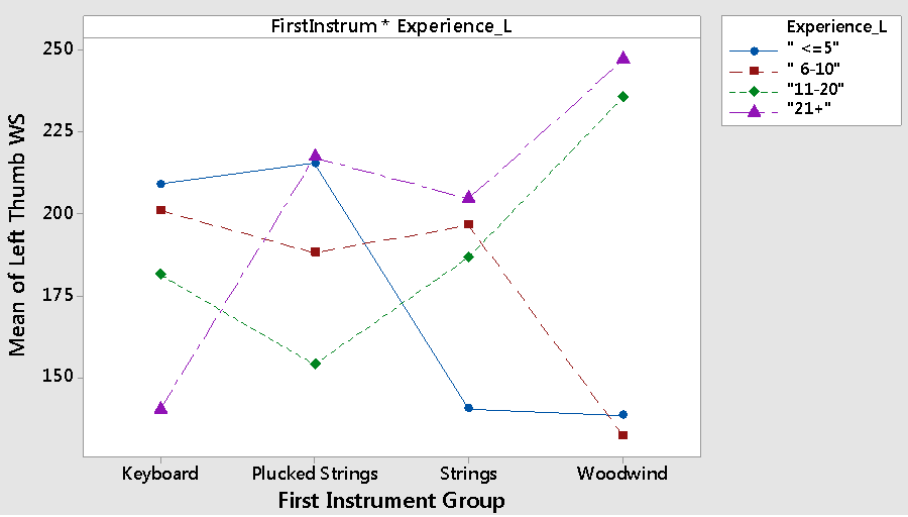


Figure 5.19. The interaction plot of female left thumb weighted scores according to the first instrument group

5.1.5.22. Left Thumb Weighted Score and Males. The first instrument group was found to be significant for left thumb weighted scores of males according to the ANOVA results illustrated in Table 5.58. According to the results of Bonferroni pairwise comparisons in Table 5.59, male musicians who were playing woodwind instruments had the highest weighted scores among all instruments and the weighted scores of plucked strings, strings and woodwind instruments were significantly higher than the weighted scores of brass instrument players. Since the assumptions of ANOVA were not satisfied before and after the application of log(Y), sqrt(Y), and 1/Y transformations, ANOVA was applied on the ranked data. The unfulfilled assumptions of ANOVA are shown in Figure D.22 and Table D.22, respectively.

Table 5.58. ANOVA results for left thumb weighted scores of males

Left Thumb Weighted Scores of Males	**Df**	**Adj SS**	**Adj MS**	**F-value**	**P-value**
First Instrument Gr.	5	31651	6330.2	4.50	0.001*
Experience	3	5130	1710.1	1.22	0.306
First Instrument Gr * Experience	15	11426	761.8	0.54	0.913
Error	157	220654	1405.4		

Table 5.59. The results of Bonferroni pairwise comparisons for left thumb weighted scores of males according to the first instrument groups

	Brass	Drums and Perc.	Keyboard	Plucked Strings	Strings
Drums and Perc.	1.000	-	-	-	-
Keyboard	1.000	1.000	-	-	-
Plucked Strings	0.038*	0.089	1.000	-	-
Strings	0.029*	0.067	1.000	1.000	-
Woodwind	0.016*	0.037*	1.000	1.000	1.000

Grouping	**N**	**Mean**	**Group**
Woodwind	20	109.950	A
Strings	18	108.987	A B
Plucked Strings	59	99.592	A B
Keyboard	30	90.086	A B C
Drums and Perc.	31	75.071	B C
Brass	23	69.500	C

5.1.5.23. Right Wrist Weighted Score and Females. ANOVA results given in Table 5.60 show that all main and interaction effects of first instrument group and experience levels had a significant effect on the right wrist weighted scores of females. The results of Bonferroni pairwise comparisons in Table 5.61 explain that female musicians playing woodwind instruments had the largest weighted scores at right wrist and the weighted scores of the woodwind instruments were significantly greater than plucked strings and keyboard. For the experience level group differences, the results of Bonferroni pairwise comparisons in Table 5.62 show that the musicians with 6-10 years of experience had the highest weighted scores and they were significantly different than the weighed scores of musicians having 21 or more years of experience. The interaction plot in Figure 5.20 indicates that the woodwind players having 5 or less years of experience had the highest weighted scores and they were followed by the strings players having 5 or less years of experience. ANOVA was applied on the ranked data since the assumptions were not satisfied even after the log(Y), sqrt(Y), and 1/Y transformations were applied. The unfulfilled assumptions of ANOVA are shown in Figure D.23 and Table D.23, respectively.

Table 5.60. ANOVA results for right wrist weighted scores of females

Right Wrist Weighted Scores of Females	**Df**	**Adj SS**	**Adj MS**	**F-value**	**P-value**
First Instrument Gr.	3	26550	8850	6.42	<0.001*
Experience	3	17465	5822	4.23	0.007*
First Instrument Gr * Experience	9	44601	4956	3.60	<0.001*
Error	151	207991	1377		

Table 5.61. The results of Bonferroni pairwise comparisons for right wrist weighted scores of females according to the first instrument groups

P-values	**Keyboard**	**Plucked Strings**	**Strings**
Plucked Strings	1.000	-	-
Strings	0.017*	0.109	-
Woodwind	0.002*	0.015*	1.000
Grouping	**N**	**Mean**	**Group**
Woodwind	40	102.724	A
Strings	48	96.258	A B
Plucked Strings	38	76.369	B C
Keyboard	41	71.106	C

Table 5.62. The results of Bonferroni pairwise comparisons for right wrist weighted scores of females according to the experience levels

	Less than or equal to 5 years	**11-20 years**	**21+ years**
11-20 years	1.000	-	-
21+ years	0.042*	0.238	-
6-10 years	1.000	1.000	0.016*
Grouping	**N**	**Mean**	**Group**
6-10 years	38	94.618	A
Less than or equal to 5 years	31	93.579	A
11-20 years	37	87.267	A B
21+ years	61	70.992	B

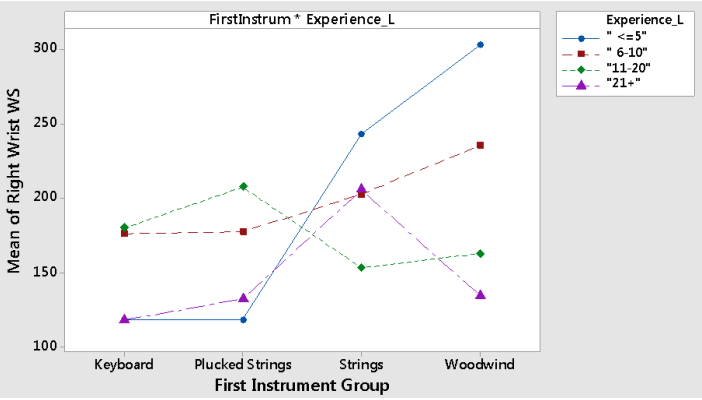


Figure 5.20. The interaction plot of female right wrist weighted scores

5.1.5.24. Right Wrist Weighted Score and Males. For the right wrist weighted scores of males, ANOVA results, which are given in Table 5.63, show that first instrument group effect was significantly important. The results of Bonferonni pairwise comparisons in

Table 5.64 show that the drums and percussion instruments' right wrist weighted scores were significantly larger than other instrument groups except strings instrument group. The weighted scores of strings instruments were found to be second largest among all instrument groups. Since the assumptions of ANOVA were not satisfied before and after the application of log(Y), sqrt(Y), and 1/Y transformations, ANOVA was applied on the ranked data. The unfulfilled assumptions of ANOVA are shown in Figure D.24 and Table D.24, respectively.

Table 5.63. ANOVA results for right wrist weighted scores of males

Right Wrist Weighted Scores of Males	**Df**	**Adj SS**	**Adj MS**	**F-value**	**P-value**
First Instrument Gr.	5	59500	11900.1	7.61	<0.001*
Experience	3	2686	895.4	0.57	0.634
First Instrument Gr * Experience	15	13327	888.5	0.57	0.896
Error	157	245545	1564.0		

Table 5.64. The results of Bonferonni pairwise comparisons for right wrist weighted scores of males according to the first instrument groups

	Brass	**Drums and Perc.**	**Keyboard**	**Plucked Strings**	**Strings**
Drums and Perc.	<0.001*	-	-	-	-
Keyboard	1.000	<0.001*	-	-	-
Plucked Strings	1.000	<0.001*	1.000	-	-
Strings	0.404	0.305	1.000	1.000	-
Woodwind	1.000	<0.001*	1.000	1.000	0.849

Grouping	**N**	**Mean**	**Group**
Drums and Perc.	31	130.264	A
Strings	18	101.216	A B
Plucked Strings	59	88.851	B
Keyboard	30	78.752	B
Woodwind	20	75.437	B
Brass	23	71.700	B

5.1.5.25. Left Wrist Weighted Score and Females. According to the ANOVA results which are given in Table 5.65, both first instrument group and experience levels were found to be significant. The results of Bonferroni pairwise comparisons in Table 5.66 show that musicians playing instruments from plucked strings instrument group had the largest weighted scores and the weighted scores are significantly different from strings and keyboard instrument groups. For experience levels, the Bonferroni pairwise comparisons in Table 5.67 point out that the female musicians having 11-20 years of experience had significantly higher left wrist scores than 21 or more years of experience group. The

interaction plot shown in Figure 5.21 explain that plucked strings players with 11-20 years of experience had the largest weighted scores and they were followed by the plucked strings players having 6-10 and 21 or more years of experience, respectively. ANOVA was applied on the ranked data since the assumptions were not satisfied even after the log(Y), sqrt(Y), and 1/Y transformations were applied. The unfulfilled assumptions of ANOVA are shown in Figure D.25 and Table D.25, respectively.

Table 5.65. ANOVA results for left wrist weighted scores of females

Left Wrist Weighted Scores of Females	**Df**	**Adj SS**	**Adj MS**	**F-value**	**P-value**
First Instrument Gr.	3	31433	10478	6.66	<0.001*
Experience	3	26265	8755	5.56	0.001*
First Instrument Gr * Experience	9	28801	3200	2.03	0.039*
Error	151	237647	1574		

Table 5.66. The results of Bonferroni pairwise comparisons for left wrist weighted scores of females according to the first instrument groups

P-values	**Keyboard**	**Plucked Strings**	**Strings**
Plucked Strings	<0.001*	-	-
Strings	1.000	0.005*	-
Woodwind	0.099	0.610	0.505
Grouping	**N**	**Mean**	**Group**
Plucked Strings	38	107.797	A
Woodwind	40	92.664	A B
Strings	48	77.269	B
Keyboard	41	70.434	B

Table 5.67. The results of Bonferroni pairwise comparisons for left wrist weighted scores of females according to the experience levels

	Less than or equal to 5 years	**11-20 years**	**21+ years**
11-20 years	0.050*	-	-
21+ years	1.000	0.002*	-
6-10 years	0.496	1.000	0.059
Grouping	**N**	**Mean**	**Group**
11-20 years	37	103.545	A
6-10 years	38	94.363	A B
Less than or equal to 5 years	31	77.499	A B
21+ years	61	72.758	B

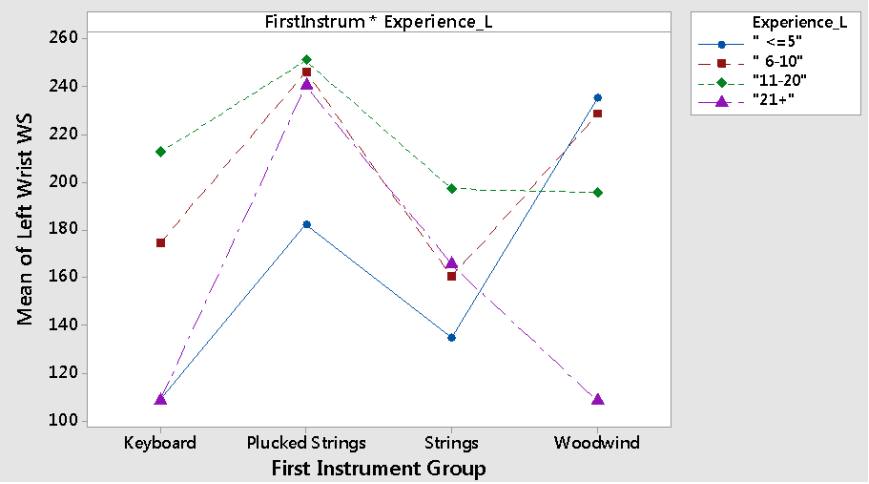


Figure 5.21. The interaction plot of female left wrist weighted scores

5.1.5.26. Left Wrist Weighted Score and Males. For the left wrist of males, the ANOVA results illustrated in Table 5.68 point out that first instrument group was a significant factor for the weighed scores. The results of Bonferroni pairwise comparisons shown in Table 5.69 explain that drums and percussion instrument group had the highest weighted scores and the weighted scores were significantly greater than keyboard, brass and woodwind instrument groups. Woodwind instrument group had significantly lower weighted scores than plucked strings, strings and drums and percussion instrument groups. Since the assumptions of ANOVA were not satisfied before and after the application of log(Y), sqrt(Y), and 1/Y transformations, ANOVA was applied on the ranked data. The unfulfilled assumptions of ANOVA are shown in Figure D.26 and Table D.26, respectively.

Table 5.68. ANOVA results for left wrist weighted scores of males

Left Wrist Weighted Scores of Males	**Df**	**Adj SS**	**Adj MS**	**F-value**	**P-value**
First Instrument Gr.	5	64147	12829.4	7.34	<0.001*
Experience	3	1978	659.3	0.38	0.769
First Instrument Gr * Experience	15	10422	694.8	0.40	0.978
Error	157	274307	1747.2		

Table 5.69. The results of Bonferroni pairwise comparisons for left wrist weighted scores of males according to the first instrument groups

	Brass	**Drums and Perc.**	**Keyboard**	**Plucked Strings**	**Strings**
Drums and Perc.	<0.001*	-	-	-	-
Keyboard	1.000	0.048*	-	-	-
Plucked Strings	0.079	0.227	1.000	-	-
Strings	0.020*	1.000	0.912	1.000	-
Woodwind	1.000	<0.001*	0.468	0.015*	0.005*

Grouping	**N**	**Mean**	**Group**
Drums and Perc.	31	121.301	A
Strings	18	111.854	A B
Plucked Strings	59	97.212	A B C
Keyboard	30	87.049	B C D
Brass	23	66.238	C D
Woodwind	20	59.500	D

5.1.5.27. Right Palm Weighted Score and Females. According to the ANOVA results shown in Table 5.70, experience level was found to be significant for right palm weighted scores of females. The results of Bonferroni pairwise comparisons shown in Table 5.71 explain that female musicians having 11-20 years of experience had the largest weighted scores, however, the weighted scores were only significantly larger than the weighted scores of the female musicians having 21 or more years of experience. ANOVA was applied on the ranked data since the assumptions were not satisfied even after the log(Y), sqrt(Y), and 1/Y transformations were applied. The unfulfilled assumptions of ANOVA are shown in Figure D.27 and Table D.27, respectively.

Table 5.70. ANOVA results for right palm weighted scores of females

Right Palm Weighted Scores of Females	**Df**	**Adj SS**	**Adj MS**	**F-value**	**P-value**
First Instrument Gr.	3	3534	1178.1	2.19	0.092
Experience	3	4375	1458.2	2.71	0.047*
First Instrument Gr * Experience	9	8343	927.0	1.72	0.089
Error	151	81342	538.7		

Table 5.71. The results of Bonferroni pairwise comparisons for right palm weighted scores of females according to the experience levels

	Less than or equal to 5 years	11-20 years	21+ years
11-20 years	1.000	-	-
21+ years	0.263	0.045*	-
6-10 years	1.000	0.333	1.000
Grouping	**N**	**Mean**	**Group**
11-20 years	37	92.606	A
Less than or equal to 5 years	38	89.119	A B
6-10 years	60	83.468	A B
21+ years	61	79.665	B

5.1.5.28. Right Palm Weighted Score and Males. ANOVA results, which are shown in Table 5.72, point out that none of the factors first instrument group or experience were significant for the right palm weighted scores of males. Since the assumptions of ANOVA were not satisfied before and after the application of log(Y), sqrt(Y), and 1/Y transformations, ANOVA was applied on the ranked data. The unfulfilled assumptions of ANOVA are shown in Figure D.28 and Table D.28, respectively.

Table 5.72. ANOVA results for right palm weighted scores of males

Right Palm Weighted Scores of Males	**Df**	**Adj SS**	**Adj MS**	**F-value**	**P-value**
First Instrument Gr.	5	7045	1409.1	1.36	0.242
Experience	3	995	331.6	0.32	0.811
First Instrument Gr * Experience	15	24336	1622.4	1.57	0.089
Error	157	162592	1035.6		

5.1.5.29. Mouth/Lips Weighted Score and Females. For the mouth/lips weighted scores of females, only the woodwind instrument players were evaluated since the other instruments were considered not to affect the mouth/lips of the musicians. Therefore, one-way ANOVA was applied in order to analyze if there was a difference between the experience levels. ANOVA assumptions were satisfied after log(Y) transformation, which are shown in Figure 5.22. An Anderson-Darling test p-value of 0.062 and Barlett's Test value of 0.849 were obtained. The unfulfilled ANOVA assumptions are shown in Figure D.29 and Table D.29, respectively. The ANOVA results in Table 5.73 show that experience levels didn't have significant effect.

Table 5.73. One-way ANOVA results for mouth/lips weighted scores of females

Mouth/Lips Weighted Scores of Females	Df	Adj SS	Adj MS	F-value	P-value
Experience	3	0.855	0.285	0.74	0.534
Error	36	13.846	0.384		

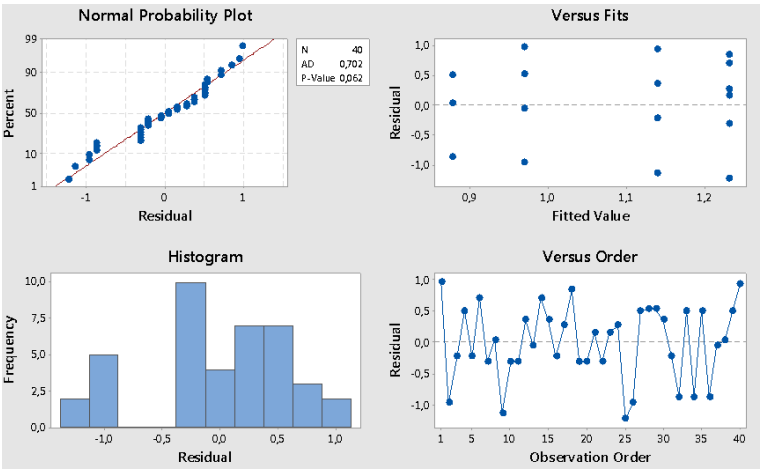


Figure 5.22. The ANOVA assumptions of mouth/lips weighted scores of females

5.1.5.30. Mouth/Lips Weighted Score and Males. The instrument groups brass and woodwind were included in the analysis as they were considered to affect the mouth/lips weighted scores directly. According to the ANOVA results in Table 5.74, first instrument group was found as significant for mouth/lips weighted scores of males. The results of Bonferroni pairwise comparisons in Table 5.75 show that brass instrument players had significantly larger weighted scores than woodwind instruments players. ANOVA assumptions were satisfied after log(Y) transformation, which are shown in Figure 5.23. An Anderson-Darling test p-value of 0.345 and Barlett's Test value of 0.878 were obtained. The unfulfilled ANOVA assumptions are shown in Figure D.30 and Table D.30, respectively.

Table 5.74. ANOVA results for mouth/lips weighted scores of males

Mouth/Lips Weighted Scores of Males	Df	Adj SS	Adj MS	F-value	P-value
First Instrument Gr.	1	7.333	7.333	6.94	0.012*
Experience	3	4.885	1.628	1.54	0.221
First Instrument Gr * Experience	3	1.287	0.429	0.41	0.750
Error	35	36.987	1.057		

Table 5.75. The results of Bonferroni pairwise comparisons for mouth/lips weighted scores of males according to the first instrument groups

P-value	**Brass**		
Woodwind	0.012*		
Grouping	**N**	**Mean**	**Group**
Brass	23	1.996	A
Woodwind	20	1.119	B

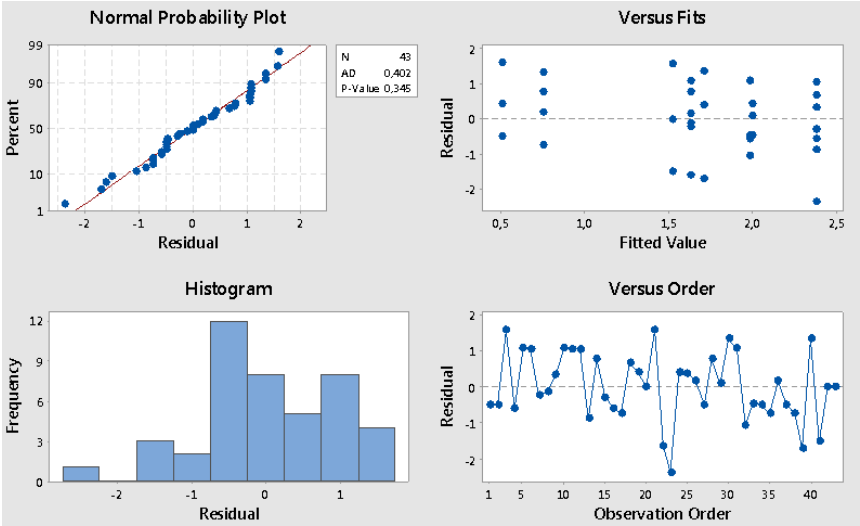


Figure 5.23. The ANOVA assumptions of mouth/lips weighted scores of males

5.1.5.31. Face/Jaws Weighted Score and Females. In order to evaluate the factors affecting face/jaws weighted scores of females, only the instrument groups woodwind and strings were taken into consideration. Strings instrument group were involved in the analyses since while musicians are playing viola or violin, they use their neck and part of their jaws for holding the instrument. ANOVA results in Table 5.76 show that the main effect of first instrument group was significant. According to the results of Bonferroni pairwise comparisons, shown in Table 5.77, woodwind instrument players had significantly larger weighted scores than strings instruments. ANOVA was applied on the ranked data since the assumptions were not satisfied even after the log(Y), sqrt(Y), and 1/Y transformations were applied. The unfulfilled assumptions of ANOVA are shown in Figure D.31 and Table D.31, respectively.

Table 5.76. ANOVA results for face/jaws weighted scores of females

Face/Jaws Weighted Scores of Females	Df	Adj SS	Adj MS	F-value	P-value
First Instrument Gr.	1	2646	2646	5.19	0.025*
Experience	3	2577	859	1.68	0.177
First Instrument Gr * Experience	3	3952	1317.2	2.58	0.059
Error	80	40817	510.2		

Table 5.77. The results of Bonferroni pairwise comparisons for female face/jaws weighted scores according to the first instrument groups

P-value	Strings		
Woodwind	0.025*		
Grouping	**N**	**Mean**	**Group**
Woodwind	40	50.323	A
Strings	48	38.838	B

5.1.5.32. Face/Jaws Weighted Score and Males. To evaluate the factors affecting face/jaws weighted scores of males, the instrument groups woodwind, strings and brass were taken into consideration. ANOVA results in Table 5.78 show that the first instrument group had significant effect on face/jaws weighted scores of males. The results of Bonferroni pairwise comparisons in Table 5.79 explain that brass instrument players had the largest weighted scores and the weighted scores they had were only significantly different from the weighted scores of woodwind players. Woodwind players had the least weighted scores among the male musicians. ANOVA assumptions were satisfied after log(Y) transformation, which are shown in Figure 5.24. An Anderson-Darling test p-value of 0.317 and Barlett's Test value of 0.826 were obtained. The unfulfilled ANOVA assumptions are shown in Figure D.32 and Table D.32, respectively.

Table 5.78. The ANOVA assumptions of face/jaws weighted scores of males

Face/Jaws Weighted Scores of Males	Df	Adj SS	Adj MS	F-value	P-value
First Instrument Gr.	2	7.669	3.835	5.82	0.005*
Experience	3	0.797	0.266	0.40	0.751
First Instrument Gr * Experience	6	3.619	0.603	0.92	0.492
Error	49	32.269	0.659		

Table 5.79. The results of Bonferroni pairwise comparisons of male face/jaws weighted scores according to the first instrument groups

P-values	**Brass**	**Strings**	
Strings	0.081	-	
Woodwind	0.005*	1.000	
Grouping	**N**	**Mean**	**Group**
Brass	23	1.301	A
Strings	18	0.681	A B
Woodwind	20	0.430	B

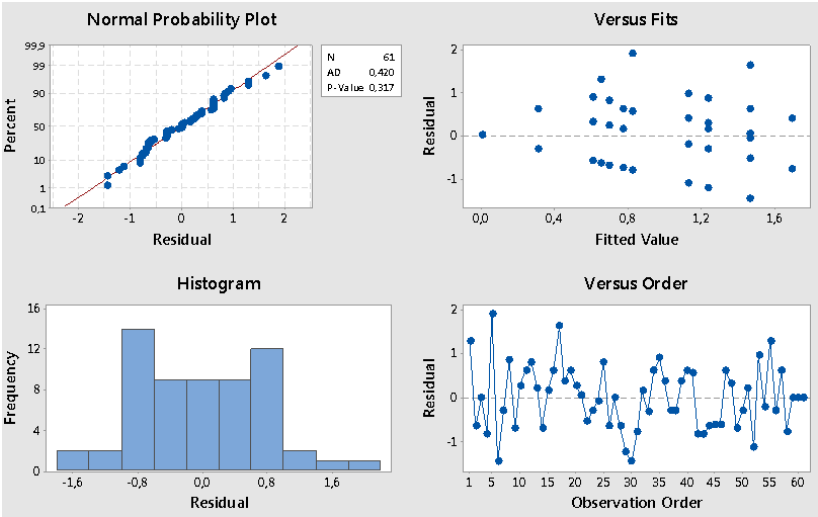


Figure 5.24. The main effects plot of male face/jaws weighted scores according to the first instrument groups

5.1.5.33. Teeth Weighted Score and Females. For evaluating the factors affecting teeth weighted scores of females, only the instrument groups woodwind and strings were taken into consideration. Strings instrument group were involved in the analyses since while musicians are playing viola or violin, they use their neck and part of their jaws for holding the instrument. This holding position also affects teeth of the musicians. The ANOVA results in Table 5.80 point out that for the teeth weighted scores of females, none of the first instrument group and experience level factors were found significant. ANOVA was applied on the ranked data since the assumptions were not satisfied even after the log(Y), sqrt(Y), and 1/Y transformations were applied. The unsatisfied assumptions of ANOVA are shown in Figure D.33 and Table D.33, respectively

Table 5.80. ANOVA results for teeth weighted scores of females

Teeth Weighted Scores of Females	Df	Adj SS	Adj MS	F-value	P-value
First Instrument Gr.	1	122.0	122.00	0.85	0.359
Experience	3	150.1	50.03	0.35	0.790
First Instrument Gr * Experience	3	812.2	270.74	1.89	0.139
Error	80	11489.1	143.61		

5.1.5.34. Teeth Weighted Score and Males. To evaluate the factors affecting teeth weighted scores of males, the instrument groups woodwind, strings and brass were taken into consideration. ANOVA results in Table 5.81 show that the first instrument group was significant. According to the results of Bonferroni pairwise comparisons in Table 5.82, brass instrument players had the highest weighted scores and it was followed by strings and woodwinds instrument groups, respectively. The weighted scores of brass players were significantly larger than the woodwind instruments players. Since the assumptions of ANOVA were not satisfied before and after the application of log(Y), sqrt(Y), and 1/Y transformations, ANOVA was applied on the ranked data. The unfulfilled assumptions of ANOVA are shown in Figure D.34 and Table D.34, respectively.

Table 5.81. ANOVA results for teeth weighted scores of males

Teeth Weighted Scores of Males	Df	Adj SS	Adj MS	F-value	P-value
First Instrument Gr.	2	1649.9	825.0	3.89	0.027*
Experience	3	706.9	235.6	1.11	0.354
First Instrument Gr * Experience	6	778.1	129.7	0.61	0.720
Error	49	10390.6	212.1		

Table 5.82. The results of Bonferroni pairwise comparisons of male teeth weighted scores according to the first instrument groups

P-values	Brass	Strings	
Strings	0.134	-	
Woodwind	0.035*	1.000	
Grouping	**N**	**Mean**	**Group**
Brass	23	38.718	A
Strings	18	28.681	A B
Woodwind	20	26.337	B

5.1.5.35. Left Elbow Weighted Score and Females. ANOVA results in Table 5.83 explain that all the main and interaction effects of first instrument groups experience levels were significant. According to the results of Bonferroni pairwise comparisons for first

instrument groups in Table 5.84, plucked strings instruments players had significantly larger weighted scores than all instrument groups except woodwind instruments. According to the results of Bonferroni pairwise comparisons for experience levels in Table 5.85, female musicians having 11-20 years of experience was found to have significantly larger weighted scores than the musicians having 21 or more years of experience. The interaction plot in Figure 5.25 shows that woodwind group instrument players with 11-20 years of experience had the highest weighted scores and they were followed by woodwind players having 5 or less years of experience and strings players having 21 or more years of experience, respectively. ANOVA was applied on the ranked data since the assumptions were not satisfied even after the log(Y), sqrt(Y), and 1/Y transformations were applied. The unsatisfied assumptions of ANOVA are shown in Figure D.35 and Table D.35, respectively

Table 5.83. ANOVA results for left elbow weighted scores of females

Left Elbow Weighted Scores of Females	**Df**	**Adj SS**	**Adj MS**	**F-value**	**P-value**
First Instrument Gr.	3	9136	3045.3	3.19	0.025*
Experience	3	7943	2647.5	2.77	0.044*
First Instrument Gr * Experience	9	23176	2575.1	2.70	0.006*
Error	151	144167	954.7		

Table 5.84. The results of Bonferroni pairwise comparisons for left elbow weighted scores of females according to the first instrument groups

P-values	**Keyboard**	**Plucked Strings**	**Strings**
Plucked Strings	<0.001*	-	-
Strings	1.000	0.005*	-
Woodwind	0.099	0.610	0.505
Grouping	**N**	**Mean**	**Group**
Plucked Strings	38	107.797	A
Woodwind	40	92.664	A B
Strings	48	77.269	B
Keyboard	41	70.434	B

Table 5.85. The results of Bonferroni pairwise comparisons for left elbow weighted scores of females according to the experience levels

	Less than or equal to 5 years	11-20 years	21+ years
11-20 years	0.050*	-	-
21+ years	1.000	0.002*	-
6-10 years	0.496	1.000	0.059
Grouping	**N**	**Mean**	**Group**
11-20 years	37	103.545	A
6-10 years	38	94.363	A B
Less than or equal to 5 years	31	77.499	A B
21+ years	61	72.758	B

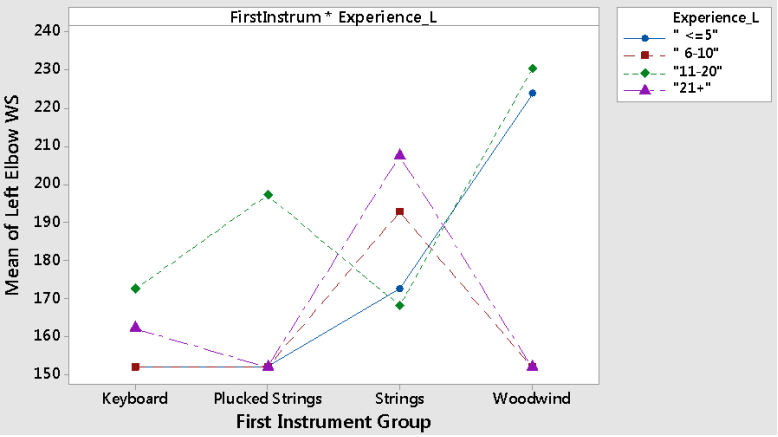


Figure 5.25. The interaction plot of female left elbow weighted scores

5.1.5.36. Left Elbow Weighted Score and Males. In Table 5.86, ANOVA results point out that the main effect of the first instrument group and the interaction effect of first instrument group and experience levels were significant for the left elbow weighted scores of males. According to the results of Bonferroni pairwise comparisons in Table 5.87, the weighted scores of strings instruments players were significantly larger than the other instrument group players. The interaction plot in Figure 5.26 show that strings players having 21 or more years of experience had the largest weighted scores and followed by strings players having 11-20 years of experience and plucked strings players having 6-10 years of experience, respectively. Since the assumptions of ANOVA were not satisfied before and after the application of log(Y), sqrt(Y), and 1/Y transformations, ANOVA was applied on the ranked data. The unfulfilled assumptions of ANOVA are shown in Figure D.36 and Table D.36, respectively.

Table 5.86. ANOVA results for left elbow weighted scores of males

Left Elbow Weighted Scores of Males	Df	Adj SS	Adj MS	F-value	P-value
First Instrument Gr.	5	30358	6071.5	8.85	<0.001*
Experience	3	2554	851.4	1.24	0.297
First Instrument Gr * Experience	15	20460	1364.0	1.99	0.019*
Error	157	107661	685.7		

Table 5.87. The results of Bonferroni pairwise comparisons for left elbow weighted scores of males according to the first instrument groups

	Brass	Drums and Perc.	Keyboard	Plucked Strings	Strings
Drums and Perc.	1.000	-	-	-	-
Keyboard	0.692	0.457	-	-	-
Plucked Strings	0.952	0.579	1.000	-	-
Strings	<0.001*	<0.001*	0.002*	<0.001*	-
Woodwind	1.000	1.000	0.756	1.000	<0.001*

Grouping	N	Mean	Group
Strings	18	127.464	A
Keyboard	30	95.656	B
Plucked Strings	59	92.816	B
Brass	23	80.000	B
Woodwind	20	80.000	B
Drums and Perc.	31	80.000	B

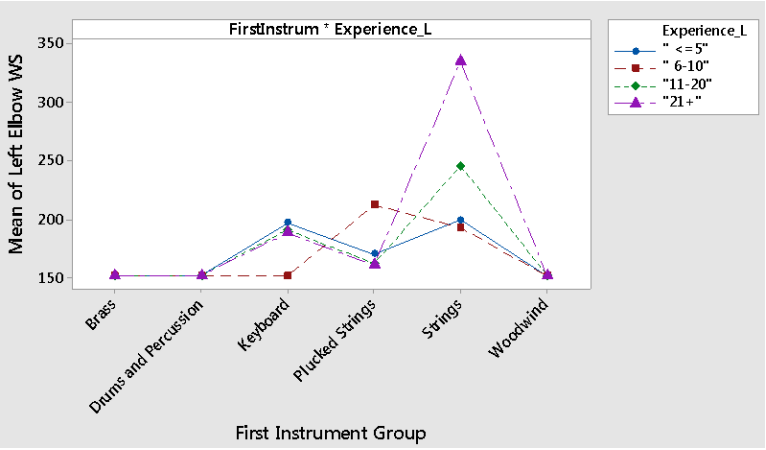


Figure 5.26. The interaction plot of male left elbow weighted scores

5.1.5.37. Right Pinkie Weighted Score and Females. ANOVA results in Table 5.88 show that all the main and interaction effects of first instrument group and experience levels were significant. According to the results of Bonferroni pairwise comparisons for first instrument groups in Table 5.89, woodwind players had the largest weighted scores and the weighted scores of woodwind players were significantly larger than the weighted scores of

plucked strings players. According to the results of Bonferroni pairwise comparisons for experience levels in Table 5.90, musicians having 5 or less years of experience had significantly larger weighted scores than the musicians having 21 or more years of experience. The interaction plot in Figure 5.27 shows that keyboard players having 5 or less years of experience had the largest weighted scores and they were followed by woodwind players having 11-20 years of experience. ANOVA was applied on the ranked data since the assumptions were not satisfied even after the log(Y), sqrt(Y), and 1/Y transformations were applied. The unsatisfied assumptions of ANOVA are shown in Figure D.37 and Table D.37, respectively

Table 5.88. ANOVA results for right pinkie weighted scores of females

Right Pinkie Weighted Scores of Females	**Df**	**Adj SS**	**Adj MS**	**F-value**	**P-value**
First Instrument Gr.	3	15997	5332	4.78	0.003*
Experience	3	14914	4971	4.46	0.005*
First Instrument Gr * Experience	9	27597	3066	2.75	0.005*
Error	151	168337	1115		

Table 5.89. The results of Bonferroni pairwise comparisons for right pinkie weighted scores of females according to the first instrument groups

P-values	**Keyboard**	**Plucked Strings**	**Strings**
Plucked Strings	0.482	-	-
Strings	1.000	0.997	-
Woodwind	0.305	0.002*	0.087
Grouping	**N**	**Mean**	**Group**
Woodwind	40	102.779	A
Keyboard	41	87.576	A B
Strings	48	84.341	A B
Plucked Strings	38	73.919	B

Table 5.90. The results of Bonferroni pairwise comparisons for left elbow weighted scores of females according to the experience levels

	Less than or equal to 5 years	11-20 years	21+ years
11-20 years	0.714	-	-
21+ years	0.004*	0.383	-
6-10 years	0.064	1.000	1.000
Grouping	**N**	**Mean**	**Group**
Less than or equal to 5 years	31	102.124	A
11-20 years	37	89.260	A B
6-10 years	38	81.144	A B
21+ years	61	76.086	B

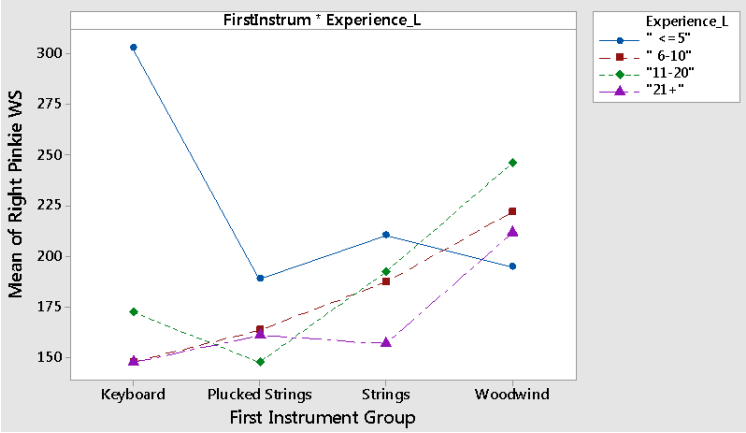


Figure 5.27. The interaction plot of female right pinkie weighted scores

5.1.5.38. Right Pinkie Weighted Score and Males. ANOVA results in Table 5.91 show that the main effect of first instrument group and the interaction effect of experience level and first instrument group was significant. The results of Bonferroni pairwise comparisons in Table 5.92 explain that woodwind players had significantly larger weighted scores than all instrument groups expect brass instruments group. The interaction plot in Figure 5.28 shows that the woodwind players having 21 or more years of experience had the largest weighted scores and followed by woodwind players with 5 or less years of experience and brass players with 5 or less years of experience, respectively. Since the assumptions of ANOVA were not satisfied before and after the application of log(Y), sqrt(Y), and 1/Y transformations, ANOVA was applied on the ranked data. The unfulfilled assumptions of ANOVA are shown in Figure D.38 and Table D.38, respectively.

Table 5.91. The ANOVA results for right pinkie weighted scores of males

Right Pinkie Weighted Scores of Males	Df	Adj SS	Adj MS	F-value	P-value
First Instrument Gr.	5	10078	2015.6	3.68	0.004*
Experience	3	3518	1172.6	2.14	0.098
First Instrument Gr * Experience	15	16554	1103.6	2.01	0.017*
Error	157	86087	548.3		

Table 5.92. The results of Bonferroni pairwise comparisons for right pinkie weighted scores of males according to the first instrument groups

	Brass	Drums and Perc.	Keyboard	Plucked Strings	Strings
Drums and Perc.	0.644	-	-	-	-
Keyboard	1.000	1.000	-	-	-
Plucked Strings	1.000	1.000	1.000	-	-
Strings	1.000	1.000	1.000	1.000	-
Woodwind	1.000	0.003*	0.012*	0.019*	0.151

Grouping	N	Mean	Group	
Woodwind	20	110.417	A	
Brass	23	97.667	A	B
Plucked Strings	59	89.790		B
Strings	18	89.714		B
Keyboard	30	80.056		B
Drums and Perc.	31	83.500		B

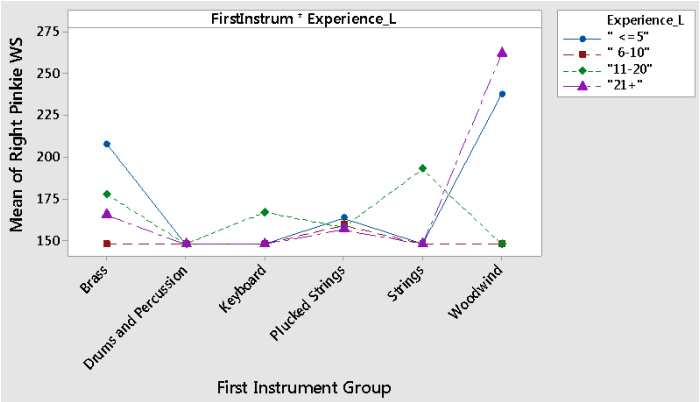


Figure 5.28. The interaction plot of male right pinkie weighted scores

5.1.5.39. The Summary of the Results for Instrument Groups. ANOVA and post-hoc analyses' summary results for each musical instrument group are illustrated in Table 5.93. The information in the table was prepared by considering the musical instruments' risks for symptoms or injuries, and the first three musical instruments which have a significant large weighted score value was considered to be risky for a weighted score at a specific part of the body. Furthermore, in order to add the interaction effects' results to the summary table,

the first three largest weighted scores in the interaction plot were added to the table by stating the experience levels having the risk of playing related disorders. All the results in the table were summarized separately for male and female genders, since all the ANOVAs were applied for both genders.

Table 5.93. The summary results for instrument groups and body parts considered as risky

Instrument Groups	**Body Parts Considered to be Risky**	
	Male Musicians	**Female Musicians**
Strings	Neck Right Shoulder Left Shoulder Right Thumb Left Thumb Right Wrist Left wrist Face/Jaws Teeth Left Elbow	Total Body Ears Left Shoulder for 21+ years of exp. Upper Back Lower Back Right Thumb Right Wrist Left Elbow for 21+ years of exp.
Keyboard	Upper Back Right Bottom of Thumb Left Bottom of Thumb	Left Shoulder for $\leq$ 5 years of exp. Lower Back for 21+ and 11-20 years of exp. Left Bottom of Thumb Left Wrist Right Pinkie
Plucked Strings	Left Shoulder Upper Back Left Bottom of Thumb Left Wrist Left Elbow for 6-10 years of exp.	Left Shoulder for 11-20 and $\leq$ 5 years of exp. Upper Back for 11-20 years of exp. Left Bottom of Thumb Left Thumb for $\leq$ 5 years of exp. Right Wrist for 11-20 years of exp. Left Wrist
Woodwind	Ears for 21+ years of exp. Neck Right Shoulder Left Shoulder Lower Back Right Bottom of Thumb Left Bottom of Thumb Right Thumb Left Thumb Right Pinkie	Ears Right Shoulder Upper Back Right Thumb Right Wrist Mouth/Lips Face/Jaws Left Elbow for 11-20 years of exp. Right Pinkie
Brass	Neck Mouth/Lips Face/Jaws Teeth Right Pinkie	-
Drums and Percussion	Ears Upper Back Lower Back Right Wrist Left Wrist	-

For strings instruments, the common body parts at risk for males and females were left shoulder, right thumb and left elbow, while males had large weighted scores at body parts of neck, right shoulder, left thumb, right wrist, left wrist, face/jaws, and teeth. Females had large weighted scores at whole body, ears, upper back, lower back, and right wrist. For keyboard instruments, the common large weighted score body part were only the left bottom of thumb. Males had large weighted scores at upper back and right bottom of thumb, while females had large weighted scores at left shoulder, lower back, left wrist, and right pinkie.

The common large weighted score areas at the males and females' body for the plucked strings instruments were left shoulder, upper back, left bottom of thumb, and left wrist. Males had large weighted scores at left elbow while females had large weighted scores at right wrist and left thumb. For the woodwind instruments, females and males both had large weighted scores at ears, right shoulder, right thumb, and right pinkie. Males had large weighted scores at neck, left shoulder, lower back, right and left bottom of thumb and left thumb while females had large weighted scores at upper back, right wrist, mouth/lips, face/jaws, and left elbow.

Since the brass and drums and percussion instruments were only played by males in this study, weighted scores of these instruments were analyzed only for males. For the brass instruments, large weighted scores were found to be at the neck, mouth/lips, face/jaws, teeth and right pinkie. Moreover, drums and percussion instrument players had large weighted scores at ears, upper back, lower back, right wrist, and left wrist.

For the experience levels, Table 5.94 shows the summary results of ANOVAs applied. The male musicians having 5 years or less experience had large weighted scores at right pinkie while females had large weighted scores at neck, left shoulder, upper back, right and left thumb, right and left wrist and right palm. The male musicians with 6-10 years of experience had large weighted scores at left elbow while the female musicians had this experience level had large weighted scores at right and left wrist, right palm, left elbow and right pinkie.

The male musicians with 11-20 years of experience had large weighted scores at left elbow while the female musicians' ears, upper back, lower back, right and left thumb, right and left wrist, right palm, left elbow, and right pinkie were the body parts having large weighted scores. Male musicians having 21 or more years of experience had risks at their ears, right pinkie and left elbow while the females had risks for playing related symptoms at ears, neck, left shoulder, upper and lower back, and left thumb.

Table 5.94. The summary results for experience levels and body parts considered as risky

Experience Levels	**Body Parts Considered to be Risky**	
	Male Musicians	**Female Musicians**
≤ 5 Years of Experience	Right pinkie for woodwind and brass	Neck Left shoulder for keyboard Upper back for woodwind Right thumb for keyboard and woodwind Left thumb for plucked Right wrist Left wrist Right palm
6-10 Years of Experience	Left elbow for plucked strings	Right wrist Left wrist Right palm Left elbow Right pinkie
11-20 Years of Experience	Left elbow for strings	Ears for woodwind Upper back for woodwind Lower back for keyboard Right thumb for woodwind Left thumb for woodwind Right wrist Left wrist Right palm Left elbow Right pinkie
21+ Years of Experience	Ears Right pinkie for woodwind Left elbow for strings	Ears for woodwind and strings Neck Left shoulder for plucked strings and strings Upper back for strings Lower back for keyboard and strings Left thumb for woodwind

5.1.6. Logistic Regression

The factors affecting the prevalence and the performance interference of the musical instrument playing related symptoms were investigated by using logistic regression. Even though in the previous section only the factors experience, gender and first instrument were

investigated with ANOVA and significant results were found, the other factors such as weekly playing time, practice session duration etc. were involved in the analyses in this section. Furthermore, different from the previous section, the output was selected to be binary for logistic regression. For prevalence outcomes, "0" means that participant doesn't have symptoms while "1" means that the participant has symptoms. For performance interference outcomes, "0" means that participant doesn't have performance interference while "1" means that the participant has performance interference. Subjects' body parts which had the highest weighted scores in Table 5.7 and ears were checked if there was a symptom or not for prevalence analyses, and checked if the musical performance was affected at that body part or not for musical performance interference analyses.

The important five body parts with the top five highest weighted scores as stated in Table 5.7 was analyzed as outcomes, also the ears were added to the analyses since it is an important body part for musicians. The total body prevalence was excluded from the analyses in this section since most of the musicians (%98.28) had symptoms at least one body part. Moreover, the performance interference of ears was excluded only from the musical performance interference analysis because only a small amount (%2.87) of participants had musical performance interference at ears.

In order to develop and test the logistic regression model, firstly the data were randomly divided into two sets called the training and the test set. The train data consisted of randomly selected %75 of the data, while the %25 of the data are used for testing the model. Backward stepwise logistic regression procedure was applied and the models were developed by using the data in the train set. Two or three models were developed for each outcome and the selection of the perfect model was performed by ROC curve plotting and AUC calculation by using the test set. The test set AUC statistic of each models was used for testing the prediction capacity of the models developed by train set.

For each output, backward stepwise regression procedure was started with two different factor combinations and two models were developed for each output. The first model included all the factors investigated in Table 4.4 while the second and third model consisted of only the significant factors from the first model. After all the models' backward stepwise regression procedures were started, the best fitting models with the

lowest AIC value were found out as a result of backward logistic regression. Then, the model with the highest AUC value from two or three best-fitting models were selected to be the perfect model for each outcome. The backward stepwise regression starting factors of each output and the AUC values of the models are shown in Table 5.95 and Table 5.96, respectively. Also in Table 5.96, the figure references in the Appendix-E section of the ROC Curves developed are shown.

Table 5.95. The backward stepwise logistic regression factors for the first models

Output	**Backward Stepwise Logistic Regression Starting Factors**		
	Model-1	**Model-2**	**Model-3**
Ears Prevalence	All factors	• Experience • First instrument group	-
Neck Prevalence	All factors	• Experience • Gender • Daily Cell Phone Use	-
Right Shoulder Prevalence	All factors	• First instrument group • Gender	-
Left Shoulder Prevalence	All factors	• Gender • Rest Duration • Playing more than one instrument	-
Upper Back Prevalence	All factors	• Daily stress (categorical) • Daily computer use	-
Lower Back Prevalence	All factors	• First instrument group • Daily cell phone use	-
Total Body Performance Int.	All factors	• First Instrument Group • Musical stress (categorical) • Regular exercise each week • Playing more than one instrument	-
Neck Performance Int.	All factors	• Experience • BMI	-
Right Shoulder Performance Int.	All factors	• Playing more than one instrument	-
Left Shoulder Performance Int.	All factors	• Gender • Playing more than one instrument	• Playing more than one instrument
Upper Back Performance Int.	All factors	• Playing more than one instrument	-
Lower Back Performance Int.	All factors	• BMI	-

Table 5.96. The AUC values and ROC curve references of the models developed for each output

Output	AUC Values			ROC Curves of Models
	Model-1	Model-2	Model-3	
Ears Prevalence	0.784	0.806	-	Figure E.1
Neck Prevalence	0.715	0.690	-	Figure E.2
Right Shoulder Prevalence	0.794	0.794	-	Figure E.3
Left Shoulder Prevalence	0.735	0.654	-	Figure E.4
Upper Back Prevalence	0.708	0.625	-	Figure E.5
Lower Back Prevalence	0.688	0.677	-	Figure E.6
Total Body Performance Int.	0.743	0.698	-	Figure E.7
Neck Performance Int.	0.808	0.745	-	Figure E.8
Right Shoulder Performance Int.	0.753	0.601	-	Figure E.9
Left Shoulder Performance Int.	0.797	0.655	0.686	Figure E.10
Upper Back Performance Int.	0.734	0.605	-	Figure E.11
Lower Back Performance Int.	0.788	0.629	-	Figure E.12

After the prediction capacity of the models developed for each output with train set (75%) were tested, the final models were developed with all the data by combining the test and the train set.

5.1.6.1. Ears Prevalence Final Model. The final model of ears prevalence is shown in Table 5.97. Increasing years of experience, weekly time spent playing, daily cell phone usage, playing instruments from drums and percussion resulted in increased risk of symptoms at ears while playing instruments from keyboard and plucked strings instrument families lowered the risk of symptoms. However, the effect of daily cell phone usage can be considered as random since there is no logical explanation of ears prevalence and using daily cell phone for text messaging, surfing the internet and other purposes. The mathematical model of the ears prevalence is shown in Equation 5.1.

Table 5.97. Final model for ears prevalence

Coefficients	**Estimate**	**Std. Error**	**z value**	**Pr(>|z|)**	**Odds Ratios**
(Intercept)	-2.64466	0.70578	-3.747	<0.001*	0.071*
Experience	0.03831	0.01333	2.873	0.004*	1.039*
First Instrument Group Drums and Percussion	1.71880	0.62108	2.767	0.006*	5.578*
First Instrument Group Keyboard	-1.83926	0.65852	-2.793	0.005*	0.159*
First Instrument Group Plucked Strings	-1.70573	0.61662	-2.766	0.006*	0.182*
First Instrument Group Strings	-0.89713	0.57701	-1.555	0.120	0.407
First Instrument Group Woodwind	0.28146	0.54788	0.514	0.607	1.325
Weekly Time Spent Playing	0.03761	0.01470	2.558	0.011*	1.038*
Daily Cell Phone Usage	0.21289	0.10307	2.065	0.039*	1.237*
Null deviance: 367.84 on 347 degrees of freedom Residual deviance: 280.81 on 339 degrees of freedom AIC: 298.81					

$$\begin{aligned}\ln\left(\frac{p(ears\ discomfort)}{1-p(ears\ discomfort)}\right) &= -2.645 + 0.038 \times Experience \\ &+ 1.718 \times First\ Instrument\ Group\ Drums\ and\ Percussion \\ &- 1.839 \times First\ Instrument\ Group\ Keyboard \\ &- 1.706 \times First\ Instrument\ Group\ Plucked\ Strings \\ &- 0.897 \times First\ Instrument\ Group\ Strings \\ &+ 0.281 \times First\ Instrument\ Group\ Woodwind \\ &+ 0.038 \times Weekly\ Time\ Spent\ Playing + 0.213 \times Daily\ Cell\ Phone\ Use\end{aligned} \quad (5.1)$$

5.1.6.2. Neck Prevalence. The final model of neck prevalence is shown in Table 5.98. According to the final model's results, having more years of experience, increasing weekly time spent playing and the daily time spent using a cell phone increased the risk of symptoms at neck while being male and increasing the practice session duration decreased the risk of symptoms. The mathematical model of the neck prevalence is shown in Equation 5.2.

Table 5.98. Final Model for Neck Prevalence

Coefficients	Estimate	Std. Error	z value	Pr(>|z|)	Odds Ratios
(Intercept)	0.037673	0.433927	0.087	0.930	1.039
Experience	0.032803	0.011186	2.933	0.003*	1.033*
Gender Male	-0.961069	0.242179	-3.968	<0.001*	0.382*
Weekly Time Spent Playing	0.033296	0.012952	2.571	0.010*	1.034*
Practice Session Duration	-0.009608	0.004588	-2.094	0.036*	0.990*
Daily Cell Phone Usage	0.205370	0.084438	2.432	0.015*	1.228*
Null deviance: 460.96 on 347 degrees of freedom Residual deviance: 413.85 on 342 degrees of freedom AIC: 425.85					

$$\ln\left(\frac{p(neck\ discomfort)}{1-p(neck\ discomfort)}\right) = 0.038 + 0.033 \times Experience - 0.961 \times Gender\ Male + 0.033 \times Weekly\ Time\ Spent\ Platying - 0.01 \times Practice\ Session\ Duration + 0.205 \times Daily\ Cell\ Phone\ Usage \quad (5.2)$$

5.1.6.3. Right Shoulder Prevalence. For right shoulder prevalence, the final model developed shown in Table 5.99, shows that playing instruments from strings, plucked strings and woodwind instrument families increased the risk of symptoms at right shoulder while being male decreased the risk of symptoms. The mathematical model of the right shoulder prevalence is shown in Equation 5.3.

Table 5.99. Final Model for Right Shoulder Prevalence

Coefficients	Estimate	Std. Error	z value	Pr(>|z|)	Odds Ratios
(Intercept)	-1.7476	0.7817	-2.236	0.025*	0.174*
First Instrument Group Drums and Percussion	0.1178	0.9572	0.123	0.902	1.125
First Instrument Group Keyboard	1.3793	0.7969	1.731	0.083	3.972
First Instrument Group Plucked Strings	1.8830	0.7748	2.430	0.015*	6.573*
First Instrument Group Strings	2.4143	0.8028	3.007	0.003*	11.182*
First Instrument Group Woodwind	2.5052	0.8039	3.116	0.002*	12.245*
Gender Male	-0.6037	0.2524	-2.392	0.017*	0.547*
Null deviance: 476.85 on 347 degrees of freedom Residual deviance: 419.31 on 341 degrees of freedom AIC: 433.31					

$$\ln\left(\frac{p(right\ shoulder\ discomfort)}{1-p(right\ shoulder\ discomfort)}\right) = -1.747 + 0.118 \times First\ Instrument\ Group\ Drums\ and\ Percussion + 1.379 \times First\ Instrument\ Group\ Keyboard + 1.883 \times First\ Instrument\ Group\ Plucked\ Strings + 2.414 \times First\ Instrument\ Group\ Strings + 2.505 \times First\ Instrument\ Group\ Woodwind - 0.604 \times Gender\ Male \quad (5.3)$$

5.1.6.4. Left Shoulder Prevalence. According to the final model developed for left shoulder prevalence shown in Table 5.100, playing more than one instrument increased the risk of symptoms at left shoulder. The mathematical model of the left shoulder prevalence is shown in Equation 5.4.

Table 5.100. Final Model for Left Shoulder Prevalence

Coefficients	**Estimate**	**Std. Error**	**z value**	**Pr(>|z|)**	**Odds Ratios**
(Intercept)	-17.8048	816.6282	-0.022	0.983	1.85e-08
First Instrument Group Drums and Percussion	15.4284	816.6284	0.019	0.985	5.02e+06
First Instrument Group Keyboard	17.2815	816.6282	0.021	0.9831	3.20e+07
First Instrument Group Plucked Strings	17.9260	816.6282	0.022	0.983	6.10e+07
First Instrument Group Strings	17.6579	816.6282	0.022	0.983	4.62e+07
First Instrument Group Woodwind	17.3364	816.6282	0.021	0.983	3.38e+07
Playing more than one instrument Yes	0.4812	0.2377	2.024	0.043 *	1.618*
Null deviance: 476.33 on 347 degrees of freedom Residual deviance: 416.93 on 341 degrees of freedom AIC: 430.93					

$$\ln\left(\frac{p(left\ shoulder\ discomfort)}{1-p(left\ shoulder\ discomfort)}\right) = -17.805 + 15.428 \times First\ Instrument\ Group\ Drums\ and\ Percussion + 17.282 \times First\ Instrument\ Group\ Keyboard + 17.926 \times First\ Instrument\ Group\ Plucked\ Strings + 17.658 \times First\ Instrument\ Group\ Strings + 17.336 \times First\ Instrument\ Group\ Woodwind - 0.481 \times Playing\ more\ than\ one\ instrument\ Yes \quad (5.4)$$

5.1.6.5. Upper Back Prevalence. For upper back prevalence, the final model which is shown in Table 5.101 shows that high daily stress level increased the risk of symptoms at upper back. The mathematical model of the upper back prevalence is shown in Equation 5.5.

Table 5.101. Final Model for Upper Back Prevalence

Coefficients	Estimate	Std. Error	z value	Pr(>|z|)	Odds Ratios
(Intercept)	-17.55436	808.63372	-0.022	0.983	2.38e-08
First Instrument Group Drums and Percussion	17.61038	808.63377	0.022	0.983	4.45e+07
First Instrument Group Keyboard	17.32676	808.63372	0.021	0.983	3.35e+07
First Instrument Group Plucked Strings	17.45105	808.63371	0.022	0.983	3.79e+07
First Instrument Group Strings	18.23256	808.63373	0.023	0.982	8.28e+07
First Instrument Group Woodwind	17.93936	808.63373	0.022	0.982	6.18e+07
Weekly time spent playing	-0.02011	0.01142	-1.762	0.078	0.980
Daily Stress ≥3	0.50154	0.23660	2.120	0.034*	1.651*
Null deviance: 482.42 on 347 degrees of freedom Residual deviance: 432.14 on 340 degrees of freedom AIC: 448.14					

$$\ln\left(\frac{p(upper\ back\ discomfort)}{1-p(upper\ back\ discomfort)}\right) = -17.554 + 17.610 \times First\ Instrument\ Group\ Drums\ and\ Percussion + 17.326 \times First\ Instrument\ Group\ Keyboard + 17.451 \times First\ Instrument\ Group\ Plucked\ Strings + 18.232 \times First\ Instrument\ Group\ Strings + 17.939 \times First\ Instrument\ Group\ Woodwind - 0.020 \times Weekly\ time\ spent\ playing + Daily\ Stress\ \geq 3 \quad (5.5)$$

5.1.6.6. Lower Back Prevalence. According to the results of the final model developed for lower back prevalence shown in Table 5.102, playing instruments from drums and percussion, keyboard and plucked strings families and increasing the daily cell phone usage time the increased the risk of having symptoms at lower back. The mathematical model of the lower back prevalence is shown in Equation 5.6.

Table 5.102. Final Model for Lower Back Prevalence

Coefficients	Estimate	Std. Error	z value	Pr(>|z|)	Odds Ratios
(Intercept)	-1.68329	0.53319	-3.157	0.002*	0.185*
First Instrument Group Drums and Percussion	2.54820	0.66419	3.837	<0.001*	12.784*
First Instrument Group Keyboard	1.68535	0.54297	3.104	0.002*	5.394*
First Instrument Group Plucked Strings	1.06208	0.52411	2.026	0.043*	2.892*
First Instrument Group Strings	0.64488	0.54290	1.188	0.234	1.905
First Instrument Group Woodwind	0.88444	0.54670	1.618	0.105	2.422
Daily Cell Phone Usage	0.21589	0.07644	2.824	0.005*	1.241*
Null deviance: 482.43 on 347 degrees of freedom Residual deviance: 448.12 on 341 degrees of freedom AIC: 462.12					

$$\ln\left(\frac{p(lower\ back\ discomfort)}{1-p(lower\ back\ discomfort)}\right) = -1.683 + 2.548 \times First\ Instrument\ Group\ Drums\ and\ Percussion + 1.685 \times First\ Instrument\ Group\ Keyboard + 1.062 \times First\ Instrument\ Group\ Plucked\ Strings + 0.645 \times First\ Instrument\ Group\ Strings + 0.884 \times First\ Instrument\ Group\ Woodwind - 0.216 \times Daily\ cell\ phone\ usage \quad (5.6)$$

5.1.6.7. Total Body Performance Interference. For the total body performance interference outcome, the details of the final model are given in Table 5.103. The results show that playing instruments from drums and percussion, strings, plucked strings and woodwind instrument families and playing more than one instrument increased the risk of performance interference for whole body. Moreover, the risk of performance interference at whole body was found to increase with exercising regularly each week, however, this was not a logical result because exercising regularly will result in strengthening the body muscles and prevent symptoms and performance interference. Hence, this factors' effect was considered as random. The mathematical model of the total body performance interference is shown in Equation 5.7.

Table 5.103. Final Model for Total Body Performance Interference

Coefficients	**Estimate**	**Std. Error**	**z value**	**Pr(>|z|)**	**Odds Ratios**
(Intercept)	-1.1050	0.4762	-2.320	0.020*	0.331*
First Instrument Group Drums and Percussion	1.5324	0.6038	2.538	0.011*	4.629*
First Instrument Group Keyboard	0.8605	0.5095	1.689	0.091	2.364
First Instrument Group Plucked Strings	0.9784	0.4926	1.986	0.047*	2.660*
First Instrument Group Strings	1.8579	0.5440	3.415	0.001*	6.411*
First Instrument Group Woodwind	1.2667	0.5314	2.384	0.017*	3.550*
Regular exercise each week Yes	0.5811	0.2416	2.405	0.016*	1.788*
Playing more than one instrument Yes	0.7423	0.2490	2.981	0.003*	2.101*
Null deviance: 445.73 on 347 degrees of freedom Residual deviance: 412.74 on 340 degrees of freedom AIC: 428.74					

$$\ln\left(\frac{p(total\ body\ performance\ interference)}{1-p(total\ body\ performance\ interference)}\right) = -1.105 + 1.532 \times First\ Instrument\ Group\ Drums\ and\ Percussion + 0.861 \times First\ Instrument\ Group\ Keyboard + 0.978 \times First\ Instrument\ Group\ Plucked\ Strings + 1.858 \times First\ Instrument\ Group\ Strings + 1.267 \times First\ Instrument\ Group\ Woodwind + 0.581 \times Regular\ exercise\ each\ week\ yes + 0.742\ Playing\ more\ than\ instruments\ yes \quad (5.7)$$

5.1.6.8. Neck Performance Interference. The details of the final model developed for neck performance interference, which are shown in Table 5.104, showed that increasing the years of experience and daily cell phone usage increased the risk of having musical performance interference at neck while being male reduced the risk of having performance interference. The mathematical model of the neck performance interference is shown in Equation 5.8.

Table 5.104. Final Model for Neck Performance Interference

Coefficients	**Estimate**	**Std. Error**	**z value**	**Pr(>|z|)**	**Odds Ratios**
(Intercept)	-1.95633	0.43478	-4.500	<0.001*	0.141*
Experience	0.02962	0.01158	2.559	0.011*	1.030*
Gender Male	-1.76234	0.32414	-5.437	<0.001*	0.172*
Daily Cell Phone Usage	0.27233	0.09824	2.772	0.006*	1.313*
Null deviance: 349.39 on 347 degrees of freedom Residual deviance: 304.73 on 344 degrees of freedom AIC: 312.73					

$$\ln\left(\frac{p(neck\ performance\ interference)}{1-p(neck\ performance\ interference)}\right) = -1.956 + 0.03 \times Experience - 1.762 \times Gender\ male + 0.272 \times Daily\ cell\ phone\ usage \quad (5.8)$$

5.1.6.9. Right Shoulder Performance Interference. According to the final model's results, which can be seen in Table 5.105, playing more than one instrument increased the risk of right shoulder performance interference. The mathematical model of the right shoulder performance interference is shown in Equation 5.9.

Table 5.105. Final Model for Right Shoulder Performance Interference

Coefficients	Estimate	Std. Error	z value	Pr(>|z|)	Odds Ratios
(Intercept)	-2.89327	0.39126	-7.395	<0.001*	0.055*
Experience	0.02458	0.01265	1.943	0.052	1.024
Playing more than one instrument Yes	0.89771	0.01265	2.605	0.009*	2.454*
Null deviance: 260.28 on 347 degrees of freedom Residual deviance: 250.85 on 345 degrees of freedom AIC: 256.85					

$$\ln\left(\frac{p(right\ shoulder\ performance\ interference)}{1-p(right\ shoulder\ performance\ interference)}\right) = -2.893 + 0.025 \times Experience + 0.898 \times Playing\ more\ than\ one\ instrument\ yes \quad (5.9)$$

5.1.6.10. Left Shoulder Performance Interference. According to the results of the final model which is shown in Table 5.106, playing more than one instrument increased the risk of left shoulder performance interference. The mathematical model of the left shoulder performance interference is shown in Equation 5.10.

Table 5.106. Final Model for Left Shoulder Performance Interference

Coefficients	Estimate	Std. Error	z value	Pr(>|z|)	Odds Ratios
(Intercept)	-2.26430	0.36286	-6.240	<0.001*	0.104*
Daily Computer Use	-0.14347	0.07935	-1.808	0.071	0.866
Playing more than one instrument Yes	1.09633	0.36591	2.996	0.003*	2.993*
Null deviance: 248.28 on 347 degrees of freedom Residual deviance: 233.59 on 345 degrees of freedom AIC: 239.59					

$$\ln\left(\frac{p(left\ shoulder\ performance\ interference)}{1-p(left\ shoulder\ performance\ interference)}\right) = -2.264 - 0.143 \times Daily\ computer\ use + 1.096 \times Playing\ more\ than\ one\ instrument\ yes \quad (5.10)$$

5.1.6.11. Upper Back Performance Effect. The final model developed for upper back performance interference, shown in Table 5.107, explain that playing more than one instrument increased the risk of having musical performance interference at upper back. The mathematical model of the upper back performance interference is shown in Equation 5.11.

Table 5.107. Final Model for Upper Back Performance Interference

Coefficients	Estimate	Std. Error	z value	Pr(>|z|)	Odds Ratios
(Intercept)	-2.4293	0.2883	-8.426	<0.001*	0.088*
Musical Stress > 3	0.5486	0.3194	1.718	0.086	1.731
Playing more than one instrument Yes	0.6779	0.3212	2.110	0.035*	1.969*
Null deviance: 275.54 on 347 degrees of freedom Residual deviance: 268.41 on 345 degrees of freedom AIC: 274.41					

$$\ln\left(\frac{p(upper\ back\ performance\ interference)}{1-p(upper\ back\ performance\ interference)}\right) = -2.429 + 0.549 \times Musical\ stress > 3 + 0.68 \times Playing\ more\ than\ one\ instrument\ yes \quad (5.11)$$

5.1.6.12. Lower Back Performance Effect. For the lower back performance interference, the details of the final model developed, which is shown in Table 5.108 explain that playing more than one instrument increased the risk of performance interference at lower back. The mathematical model of the lower back performance interference is shown in Equation 5.12.

Table 5.108. Final Model for Lower Back Performance Interference

Coefficients	Estimate	Std. Error	z value	Pr(>|z|)	Odds Ratios
(Intercept)	-21.01158	1088.26908	-0.019	0.985	7.49e-10
Experience	0.02451	0.01379	1.778	0.075	1.025
First Instrument Group Drums and Percussion	20.78617	1088.26806	0.019	0.985	1.07e+09
First Instrument Group Keyboard	19.76820	1088.26823	0.018	0.986	3.85e+08
First Instrument Group Plucked Strings	19.59480	1088.26808	0.018	0.986	3.24e+08
First Instrument Group Strings	18.81946	1088.26785	0.017	0.986	1.49e+08
First Instrument Group Woodwind	18.56307	1088.26773	0.017	0.986	1.15e+08
Hours Spent for Sleeping	-0.25356	0.16396	-1.546	0.122	0.776
Rest Duration	0.02035	0.01205	1.689	0.091	1.021
Daily Cell Phone Usage	0.24105	0.10765	2.239	0.025*	1.272*
Playing more than one instrument Yes	0.59669	0.33626	1.774	0.076	1.816
Null deviance: 293.51 on 347 degrees of freedom Residual deviance: 259.64 on 337 degrees of freedom AIC: 281.64					

$$\ln\left(\frac{p(lower\ back\ performance\ interference)}{1-p(lower\ back\ performance\ interference)}\right)$$
$$= -21.012 + 0.025 \times Experience$$
$$+ 20.786 \times First\ Instrument\ Group\ Drums\ and\ Percussion$$
$$+ 19.768 \times First\ Instrument\ Group\ Keyboard$$
$$+ 19.595 \times First\ Instrument\ Group\ Plucked\ Strings \quad (5.12)$$
$$+ 18.819 \times First\ Instrument\ Group\ Strings$$
$$+ 18.563 \times First\ Instrument\ Group\ Woodwind$$
$$- 0.254 \times Hours\ spent\ for\ sleeping + 0.02 \times Rest\ duration$$
$$+ 0.241 \times Daily\ Cell\ Phone\ Usage$$
$$+ 0.597 \times Playing\ more\ than\ one\ instrument\ yes$$

5.1.6.13. Summary Results of the Logistic Regression Models. In order to summarize the effect of the significant factors affecting the playing related symptom prevalence and the musical performance interference, results of the logistic regression models developed are shown in Table 5.109, Table 5.110, and Table 5.111 respectively. In these tables, an up arrow is used to explain that each factor or continuous variable increases the risk of symptoms or performance effects while a down arrow is used to show a decreasing risk of symptoms or performance effects for each output. Every factor level of the categorical variables is included in the tables so that the factors having significant effects can easily be interpreted. Moreover, in the tables, the continuous variables have the information whether they are increasing or decreasing to show how the prevalence and performance interference risks changed.

Table 5.109. Summary results of logistic regression models for gender

Logistic Regression Results	**Outputs**											
Factors	**Ears Prev.**	**Neck Prev.**	**Right Shoulder Prev.**	**Left Shoulder Prev.**	**Upper Back Prev.**	**Lower Back Prev.**	**Total Body Perf. Eff.**	**Neck Perf. Eff.**	**Right Shoulder Perf. Eff.**	**Left Shoulder Perf. Eff.**	**Upper Back Perf. Eff.**	**Lower Back Perf. Eff.**
Gender: Male		↓	↓					↓				
Gender: Female												

As illustrated in Table 5.109, being male reduced the risk of neck and right shoulder prevalence and it decreased the risk for neck performance interference. The Table 5.110

shows that for ears prevalence, playing instruments from keyboard and plucked strings reduced the risk of symptoms while playing drums and percussion instruments increased the risk. For right shoulder prevalence, playing strings, plucked strings and woodwind instruments increased the symptom risk. Moreover, playing keyboard, plucked strings and drums and percussion instruments increased the risk of symptoms at lower back and playing strings, woodwind, plucked strings and drums and percussion instruments increased the risk of total body performance interference.

In Table 5.111, it is shown that increasing experience level increased the risk of symptoms at ears and neck, also it increased the risk of the neck performance interference. Moreover, playing more than one instrument increased the risk of symptoms left shoulder and increased the risk of musical performance interference at whole body, both shoulders and upper back. Furthermore, the results showed that increasing the daily cell phone usage increased the risk of ears, neck and lower back prevalence, and increased the risk of performance interference at neck and lower back. As explained before, the performance interference of ears can be considered as random since there is no logical explanation. Moreover, musicians exercising regularly each week were found to have more risk of total body performance effect. This can be explained by being active in sports might cause over exertion of the muscles during training and this might result in a performance effect at a body part, however, again it can be though as a random effect since making exercise strengthens the muscles and it might avoid playing related symptoms or injuries. Musicians having daily stress level greater than or equal to three had higher risk of symptoms at upper back. Increasing the weekly time spent playing increased the symptoms at ears and decreasing the practice session duration resulted in higher risk of symptoms at neck.

5.2. Results of the Hand Dimensions Analyses

In order to investigate the anthropometric measurements of the hand on the musical instrument playing related symptoms, the hand dimensions of 33 participants were collected. After the collection of the hand dimension data, the correlation of the weighted scores and the hand dimensions were analyzed. The hand dimensions that were taken from each subjects' both hands were handpsans, thumb and index fingers' hand spans, hand breadths, hand lengths, and the length and width of thumb, index, middle, ring and pinkie

fingers. Also, the proximal, distal and middle length of the fingers were measured, however, these lengths were only used to calculate the total length of the fingers.

Table 5.110. Summary results of Logistic Regression models for instrument group

Logistic Regression Results	**Outputs**											
Factors	**Ears Prev.**	**Neck Prev.**	**Right Shoulder Prev.**	**Left Shoulder Prev.**	**Upper Back Prev.**	**Lower Back Prev.**	**Total Body Perf. Eff.**	**Neck Perf. Eff.**	**Right Shoulder Perf. Eff.**	**Left Shoulder Perf. Eff.**	**Upper Back Perf. Eff.**	**Lower Back Perf. Eff.**
Instrument Gr. Keyboard	↓					↑						
Instrument Gr. Strings			↑				↑					
Instrument Gr. Plucked Strings	↓		↑			↑	↑					
Instrument Gr. Woodwind			↑				↑					
Instrument Gr. Brass												
Instrument Gr. Drums and Perc.	↑					↑	↑					

Table 5.111. Summary results of Logistic Regression models for other factors

Logistic Regression Results	**Outputs**											
Factors	**Ears Prev.**	**Neck Prev.**	**Right Shoulder Prev.**	**Left Shoulder Prev.**	**Upper Back Prev.**	**Lower Back Prev.**	**Total Body Perf. Eff.**	**Neck Perf. Eff.**	**Right Shoulder Perf. Eff.**	**Left Shoulder Perf. Eff.**	**Upper Back Perf. Eff.**	**Lower Back Perf. Eff.**
Experience (Increasing)	↑	↑						↑				
Playing more than one instrument: Yes				↑			↑		↑	↑	↑	
Playing more than one instrument: No												
Daily Cell Phone Use (Increasing)	↑	↑				↑		↑				↑
Regular exercise each week: Yes							↑					
Regular exercise each week: No												
Daily Stress ≥ 3					↑							
Daily Stress < 3												
Weekly time spent playing (Increasing)	↑											
Practice session duration (Decreasing)		↑										

The weighted scores at the body parts to be analyzed as outputs were selected as the body parts which have the largest weighted scores, which are shown in Table 5.7, and the weighted scores of hands. To explain in detail, weighted scores of the body parts were selected as neck, right shoulder, left shoulder, upper back, lower back, right thumb, left thumb, right index finger, left index finger, right middle finger, left middle finger, right ring finger, left ring finger, right pinkie, left pinkie, right palm, left palm, right bottom of thumb, and left bottom of thumb.

5.2.1. Hand Dimensions Correlations Before Ratio Scaling

The Spearman correlations of the selected weighted scores and all hand dimensions were calculated for the 33 subjects from whom the data were collected. According to the first correlation analysis shown in Figure E.13, left thumb weighted scores are found to be significantly and negatively correlated with left ring finger width. Moreover, the right pinkie weighted score was significantly and negatively correlated with right hand span, right thumb and index finger hand span, right hand length, also with the width dimensions of right index, middle, ring and pinkie fingers. What's more, left ring finger widths were significantly and negatively correlated left bottom of thumb weighted scores. The results show that smaller dimensions of the hands result in larger weighted scores, however, in order to increase the sample size and perform better analysis, the ratio scaling method was applied in the next section.

5.2.2. Hand Dimensions Correlations After Ratio Scaling

For increasing the sample size, the ratio scaling method was applied to the dataset with the sample size of 33. The heights of the participants were taken as a reference while applying the ratio scaling, and for appropriately enlarging the data to the other datasets, the populations which are the same in ethnicity, age group and gender was used. For that reason, the participants having family origins from other countries were excluded from ratio scaling. In order to enlarge the data, the data of Turkish male and female populations were used based on the study made by Ekşioğlu (2015). Some of the hand dimensions which were not measured in these studies, which are hand span, thumb and index finger hand span, length of thumb, middle finger, ring finger and pinkie, and width of all fingers,

were scaled from the data collected from 33 participants. The data used for scaling from the study made by Ekşioğlu (2015) are showed in Table E.7 and Table E.8.

By using the dimensions calculated from the ratio scaling, the correlations of the weighted scores for the selected body parts with the hand dimensions were calculated. The correlation analysis performed on each instrument group is explained below.

5.2.2.1. Hand Dimensions Correlations of Brass Instruments Players. According to the spearman correlation coefficients and p-values in Figure E.14, right hand span, right and left hand length, right and left thumb length, left index finger length, and right and left ring finger length were found to be positively and significantly correlated with weighted scores at neck. However, right and left index finger width, right middle finger width, right and left ring finger width, and right and left pinkie width were found to be negatively and significantly correlated with lower back weighted scores. Right thumb width was also found as negatively and significantly correlated with right palm weighted scores. Consequently, for brass players, larger hands increased the weighted scores at neck while thicker fingers reduced the weighted scores at lower back and right palm.

5.2.2.2. Hand Dimensions Correlations of Drums and Percussion Players. The spearman correlation coefficients and p-values for the correlation of hand dimensions and weighted scores of drums and percussion players are given in Figure E.15. For the drum and percussion players investigated in this study, the width of right and left thumbs, right and left index fingers, right ring finger, left middle finger, and left pinkie were found to be significantly and positively correlated with the neck weighted scores. The width of right ring finger and right and left pinkie were significantly and positively correlated with right shoulder weighted scores. However, left ring finger length, left thumb width, and left index finger width were found to be negatively and significantly correlated with left index finger weighted scores. For the drums and percussion instrument players, it can be stated that musicians with larger finger widths had more symptoms at neck and right shoulder while musicians having larger hands and thick fingers had less symptoms at left index finger.

5.2.2.3. Hand Dimensions Correlations of Keyboard Players. In Figure E.16, the spearman correlation coefficients and p-values for the correlation of hand dimensions and weighted

scores of keyboard players are given. The correlation analysis' results showed that left hand span, right and left thumb, left index finger, right and left middle finger and left middle finger were significantly and negatively correlated with neck weighted scores. Right hand length, right thumb, middle finger and ring finger length were negatively and significantly correlated with right shoulder weighted scores. What's more, right hand span, right hand breadth, right thumb, and widths of all the right hand fingers except right pinkie were found as significantly and negatively correlated with right thumb weighted scores and the widths of left hand fingers were found to be significantly and negatively correlated with left thumb weighted scores. The length of right middle and ring finger were found to be significantly and positively correlated with right index finger weighted scores. The length of right and left middle fingers were found to be significantly and positively correlated with right and left middle finger weighted scores, respectively. Right hand span and the widths of right index finger, right middle finger, and right ring fingers were significantly and negatively correlated with right pinkie weighted scores. The right thumb and middle finger length were significantly and positively correlated with right palm weighted scores. Right hand span, hand breadth, and the length of right thumb, index finger, middle finger, ring finger and index finger were found to be significantly and positively correlated with right bottom of thumb weighted scores. For keyboard players, the results of the correlation analysis can be interpreted as larger hand dimensions increased the weighted scores of right index finger, right and left middle finger, right palm, right bottom of thumb and left bottom of thumb while smaller hand dimensions increased the weighted scores at neck, right and left shoulder, right and left thumb, and right pinkie.

5.2.2.4. Hand Dimensions Correlations of Plucked Strings Players. For the plucked strings players, the results of the correlation analysis are given in Figure E.14. The weighted scores of neck were found to be negatively and significantly correlated with left hand span, left hand length, and the length of thumb, index finger and middle finger. There was also a significant and negative correlation between right shoulder weighted scores and hand dimensions of left hand span, right hand breadth, right thumb length, right pinkie length, widths of thumb, index finger, middle finger and ring finger. Left shoulder weighted scores were found to be negatively and significantly correlated with left hand span, left thumb and index finger hand span, left hand length and breadth, left index, middle and ring finger lengths, and widths of left thumb, index finger, middle finger and pinkie. There were

significant positive correlations of hand dimensions and weighted scores of the plucked strings players as well. Upper back weighted scores were significantly and positively correlated with right and left hand spans, right and left thumb and index finger hand spans, right and left hand lengths, lengths of the all right and left fingers except middle finger, and right and left pinkie width. Right index finger weighted score was significantly and positively correlated with length of all fingers, and right middle finger weighted scores were significantly and positively correlated with right middle finger length. The left hand span and left thumb and index finger hand span were positively and significantly correlated with the weighted scores of left middle finger and left ring finger weighted scores. Left hand span was significantly and positively correlated with weighted scores of left ring finger and right palm. Right palm weighted score was correlated with right hand span, right thumb and index finger hand span, right thumb, middle finger and pinkie length. Lastly, left pinkie weighted scores were found to be negatively and significantly correlated with all the hand dimensions. Therefore, for plucked strings players, larger hand dimensions resulted in higher weighted scores at upper back, right index finger, right and left middle finger, left ring finger and right palm while smaller hand dimensions increased the weighted scores at neck, right and left shoulder, and left pinkie.

5.2.2.5. Hand Dimensions Correlations of Strings Players. The correlation analysis for strings players' hand dimensions and weighted scores are shown in Figure E.18. The spearman correlation coefficients and p-values showed the right shoulder weighted scores were significantly and positively correlated with right thumb and index finger span, right thumb length, right ring finger and pinkie width. Left shoulder weighted scores were significantly and positively correlated with left thumb width. Right index finger weighted scores were negatively and significantly correlated with right hand span, right thumb and index finger hand span, length of all right hands' fingers, right index and ring finger widths. Right middle finger weighted scores were found to be significantly and positively correlated with right hand breadth, right thumb, middle finger and index finger widths. Left palm weighted scores were found to be negatively and significantly correlated with left thumb and index finger hand spans, all left hand fingers' lengths and left index finger width. There were significant and positive correlations between right middle finger weighted scores and right hand breadth and widths of right thumb, right middle finger and right pinkie. Left palm weighted scores were found to be negatively and significantly

correlated with left thumb and index finger span, lengths of all left hand fingers and left index and ring finger widths. Right bottom of thumb weighted scores were found significantly and positively correlated with right hand span, index and thumb span, right hand length and breadth, lengths of all right hand fingers except middle finger, and widths of right hand fingers except pinkie. To sum up, larger hand dimensions increased the weighted scores at right and left shoulder, right middle finger, and right bottom of thumb while smaller hand dimensions resulted in increased weighted scores of right index finger and left palm.

5.2.2.6. Hand Dimensions Correlations of Woodwind Players. Figure E.19 shows the correlation analysis for hand dimensions and weighted scores of woodwind players. The results of the correlation analysis showed that the right thumb weighted scores were significantly and positively correlated with right thumb and index finger hand span. Left ring finger weighted scores were found to be significantly and positively correlated with left hand span. Right pinkie weighted scores were significantly and negatively correlated with right hand breadth, and the widths of right thumb, middle finger and pinkie. Moreover, left palm weighted scores had significant and negative correlations with left hand breadth, left hand length, and left thumb, middle finger and pinkie width. In result, larger hand dimensions increased weighted scores of the woodwind players at right thumb and left ring finger while smaller hand dimensions increased the weighted scores of right pinkie and left palm.

5.2.2.7. Summary of the Hand Dimensions Correlations. According to the correlation analysis of hand dimensions and weighted scores made after ratio scaling for each instrument group, hand dimensions' largeness or smallness had common or different effects on the weighted scores selected. For every weighted score at each instrument group, some of the hand dimensions were significantly positively or negatively correlated with the weighted scores, however, for every weighted score there were either significantly positive or significantly negative correlations, that's why the weighted score results could be interpreted in terms of increasing or decreasing hand dimensions and their significance. In order to compare and to summarize the hand dimensions' effects on the weighted scores, the summary Table 5.112 was prepared. In this table, for each instrument group, the cells related with hand dimensions were marked with a plus sign if they were significantly and

positively correlated with the weighted scores of each body part and marked with a minus sign if they were significantly and negatively correlated with the weighted scores. If any correlation couldn't be found, then the cell was left empty.

According to the Table 5.112, for brass instruments players, larger hand dimensions resulted in increased weighted scores at neck while largeness of the hands decreased the weighted scores at lower back and right palm. For drums and percussion instruments players, larger hands resulted in higher weighted scores at neck and right shoulder and lower weighted scores at left index finger. Keyboard instrument players with larger hand dimensions had higher weighted scores at right index finger, right and left middle finger, right palm and right bottom of thumb while they had lower weighted scores at neck, right and left shoulder, lower back, right and left thumb, and right pinkie.

For plucked strings instruments players, larger hand dimensions resulted in higher weighted scores at upper back, right index finger, right and left middle finger, left ring finger and right palm and lower weighted scores at neck, right and left shoulders, and left pinkie. Strings instruments players with larger hands had higher weighted scores at right shoulder, left index finger, right middle finger, and right bottom of thumb of while smaller hands resulted in higher scores of right index finger, right ring finger, left pinkie, and left palm. For woodwind players, large hand dimensions resulted in higher weighted scores at right thumb and left index finger while small hands resulted in higher weighted scores of right pinkie and left palm.

The results of the hand dimensions' analyses showed that when considering all instrument group players, having larger hands reduced weighted scores at total body, lower back, right ring finger, right and left pinkie and left palm, however, larger hand dimensions enhanced the weighted scores of upper back, right and left middle finger, left ring finger, and right and left bottom of thumb. What's more, the correlation results also showed that for the weighted scores of neck, right and left shoulder, right and left index finger, and right palm the hand dimensions' effects on the weighted scores changed depending on the musical instrument group.

Table 5.112. Summary results for correlation analysis of hand dimensions

Hand Dimensions Correlations Analysis	Significant Hand Dimension Correlations					
Weighted Scores	**Brass Instruments Players**	**Drums and Percussion Instruments Players**	**Keyboard Instruments Players**	**Plucked Strings Instrument Players**	**Strings Instruments Players**	**Woodwind Instrument Players**
Total Body						
Neck	+	+	−	−		
Right Shoulder		+	−	−	+	
Left Shoulder			−	−		
Upper Back				+		
Lower Back	−		−			
Right Thumb			−			+
Left Thumb			−			
Right Index Finger			+	+	−	
Left Index Finger		−			+	
Right Middle Finger			+	+	+	
Left Middle Finger			+	+		
Right Ring Finger					−	
Left Ring Finger				+		+
Right Pinkie			−			−
Left Pinkie				−	−	
Right Palm	−		+	+		
Left Palm					−	−
Right Bottom of Thumb			+		+	
Left Bottom of Thumb						

5.3. Results of RULA Analysis for Musicians

The RULA analysis was applied for all the musical instrument groups classified in the study. As stated earlier, the musical instrument groups were classified as drums and percussion, keyboard, strings, plucked strings, woodwind and brass. At least one instrument from each instrument group were evaluated by using RULA analysis, the body postures during normal playing positions were analyzed. For some instruments, two playing positions were evaluated and the effect of position change as RULA score

difference was analyzed. Moreover, for the piano, two different musical piece having different playing positions were analyzed.

5.3.1. RULA Analysis of Drum Playing

For two drum playing positions, which were playing the ride cymbal and the hi-hat respectively, the RULA analysis was applied. The 26-year-old male subject was playing the drums for 12 years and he was practicing his instrument 16 hours in a week. The subject and was experiencing music related symptoms at lower back, right knee, both index fingers and ears. The first drum playing position of the subject, which is shown in Figure 5.29, was the ride cymbal playing. According to the analysis of this playing position, the left and right upper limb RULA scores were found to be 4 and 5 respectively, which can be concluded that this drum playing position should be investigated and might be changed in order to avoid playing related discomfort. The difference between the right and left upper limbs' RULA score can be explained by the difference of upper and lower arms' scores for left and right upper extremities. Right upper arm was given one more point than the left upper arm because it had back extension and the right lower arm of the subject got one more point than left lower arm since it was working outside of the body. The RULA analysis details for left and right upper limbs are shown in Figure C.2 and C.3 respectively.

Figure 5.29. Drummer first playing position: Playing the ride cymbal

The second drum playing position, which is called hi-hat playing, is shown in Figure 5.30. The RULA scores were calculated to be 5 and 4 for the left and right upper limb respectively, which indicate that for both upper limbs, playing position should be

investigated and some adjustments should be made especially for the left upper limb. The reason for the RULA score difference between left and right upper limb can be explained by the score difference of the upper arms. The score of the left upper arm got one point more than the right upper arm since there was an abduction while playing the hi-hat. The RULA analysis details for left and right upper limbs are shown in Figure C.4 and C.5 respectively.

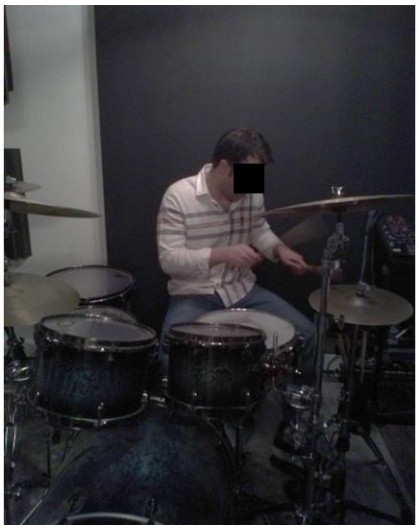


Figure 5.30. Drummer second playing position: Playing the hi-hat

5.3.2. RULA Analysis of Viola Playing

The RULA Analysis was applied for a female violist for the playing position shown in Figure 5.31. The subject was playing the viola at standing position while holding the viola by using her neck and holding the viola bow by her right hand. The female subject was 22 years old and she was playing the viola for 11 years. The weekly practice time she was spending for viola playing was 14 hours and she was feeling symptoms at face and jaws, neck and left shoulder. For this position, the subjects' both upper limbs got a RULA score of 7, which is the highest score in RULA analysis, therefore it can be concluded that the position has risks for musculoskeletal symptoms and immediate change is needed in order to avoid playing related injuries. The high RULA score can be explained by high neck, upper arm and lower arm scores. The RULA analysis details for left and right upper limbs for the violist are shown in Figure C.6 and C.7 respectively.

Figure 5.31. Violist playing position

5.3.3. RULA Analysis of Guitar Playing

A male subject was evaluated for the playing position shown in Figure 5.32 by using RULA. The subject was hanging the guitar on his body by a guitar strap while standing. The 27-years-old subject was practicing his instrument for 5 hours in a week and he was playing the guitar for 17 years. He was experiencing symptoms at upper back, right forearm, left index finger, left middle finger and left ring finger. The RULA score of the subject was 6 for both upper limbs, which means that improvements should be made in the near future for this playing position. For the left upper limb, the upper and lower arms got a score of 1 while the wrist score was 3, and for the right upper limb, the upper and lower arm scores were 2 while the wrist score was 1. The RULA analysis details for left and right upper limbs for the guitarist are shown in Figure C.8 and C.9 respectively.

Figure 5.32. Guitarist playing position

5.3.4. RULA Analysis of Keyboard Playing

A keyboard player's two different playing positions were evaluated by RULA analysis. The subject was sitting in both playing positions and he was playing the double keyboards in a similar way. The only difference between the playing positions was the upper keyboard's different placements which are illustrated in Figure 5.33 and Figure 5.34, respectively. The male subject was 27 years old and he was playing the piano and the keyboard for 20 years. He was spending 6 hours to practice the instrument in a week and experiencing symptoms at upper back, both thumbs, right index finger, right middle finger, right and left bottom of thumb and ears. The RULA scores for the first playing position was 3 and 4 for the left and right upper limb respectively. According the RULA scores, the playing position should be investigated and might be changed. The different RULA scores for right and left upper limb can be explained by the higher upper arm and wrist score for the right upper limb when compared with the left upper limb.

Figure 5.33. Keyboard playing position-1

The RULA score for the keyboard playing position-2 was 3 for both right and left upper limbs. The change of the upper keyboard positioning resulted in better playing posture. The right upper arm score was decreased to 2 points from 3 points as it was in playing position-1. The RULA analysis details of the left and right upper limbs for keyboard playing position-1 are shown at Figure C.10 and C.11 respectively, and the RULA details for the playing position-2 for left and right upper limbs are illustrated in Figure C.12 and C.13 respectively.

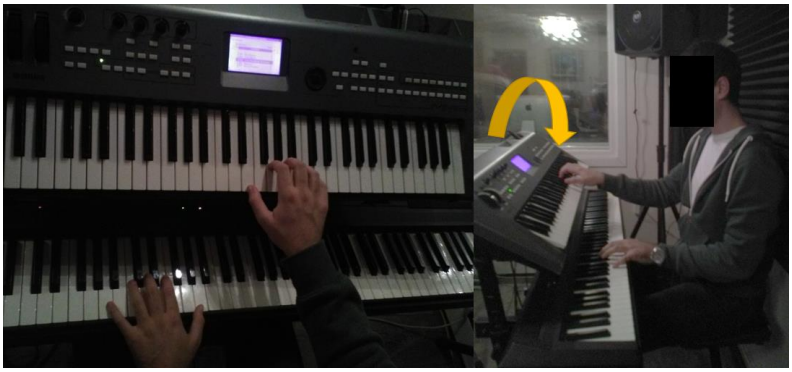


Figure 5.34. Keyboard playing position-2

5.3.5. RULA Analysis of Piano Playing

The same subject who was evaluated while playing the keyboard was re-evaluated while playing a piano by using RULA Analysis. The subject was playing the piano in the sitting position during a concert, which is illustrated in Figure 5.35. Since both upper limbs were in a symmetrical position while playing the piano, the RULA was applied for both left and right limbs together. The subject got 3 points for both upper limbs, which corresponds to a score that suggests checking playing position and making possible improvements. The RULA details of the playing the piano for left and right upper limbs are illustrated in Figure C.14.

Figure 5.35. Pianist playing position during a concert

In order to evaluate the effect of the musical repertoire on the playing position and musical instrument playing related musculoskeletal injury risks, a female subject's piano

playing positions were evaluated, which is shown in Figure 5.36, during playing two different musical pieces which were Mozart A major sonata and Liszt D-flat major etude. The subject was 63 years old and she was playing the piano for 56 years. She was practicing the instrument for 40 hours in a week and had symptoms at neck and both shoulders. For Mozart A major sonata, the subject got 3 points, which means that the playing position might be changed for ergonomic instrument playing. The details of the RULA analysis can be seen in Figure C.15.

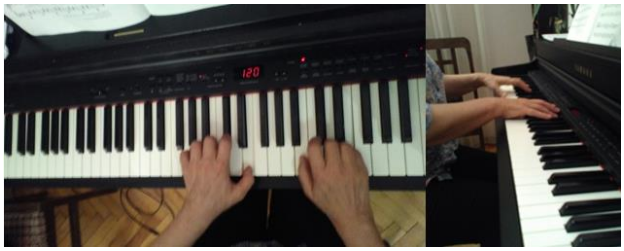


Figure 5.36. Pianist playing position for Mozart A major sonata

The subject was evaluated while playing Liszt D-flat major etude for two different playing positions. The first and second playing positions are shown in Figure 5.37. For the first playing position, both upper limbs had symmetrical playing positions, that's why they were evaluated together. The subject got 3 points for both upper limbs, which means further investigation and possible position change might be needed. For the second playing position, even though the left wrist and arm score was one point higher than the right wrist and arm score, the subject got 3 points for the left and right upper limb. It showed that playing position resulted from different repertoire didn't affect the RULA score. The RULA analysis details of for playing Liszt D-flat major etude is illustrated in Figure C.16 C.17 and C.18 respectively.

(a) (b)

Figure 5.37. Pianist first (a) and second (b) playing positions for Liszt D-flat major etude

5.3.6. RULA Analysis of Flute Playing

The flute playing position of a female subject was evaluated by RULA. The 28-year-old subject was playing her instrument for 2 years. She was practicing her instrument 2 hours in a week and she was having symptoms at neck, right upper arm, both lower arms, both wrists, right index finger, right pinkie, both hand palms and right bottom of thumb. The standing playing position while playing her instrument is illustrated in Figure 5.38. The RULA scores for both left and right upper limbs were 4, which means improvements might be made for the playing position after it is evaluated. The right upper arm score was one point higher than the left upper arm, however, both upper limbs got the same RULA score. The details of the RULA analysis for flute playing can be seen in Figure C.19 and C.20 respectively.

Figure 5.38. Flute playing position

5.3.7. RULA Analysis of Trombone Playing

A trombone players' playing position shown in Figure 5.39 was evaluated by RULA. The male subject was 20 years old and he was playing the trombone for 9 years. The time he was spending for practicing was 20 hours and he was experiencing symptoms at face/jaws, teeth, neck, right shoulder, right upper arm, lower back, both wrists, and both hand palms. The RULA score for both upper limbs were 6, which shows the playing position should be examined and it should be changed in a short time. The right upper arm score was one point more than the left upper arm, however, both upper limbs got the same

final RULA score. The details of the RULA analysis for trombone playing position is illustrated in Figure C.21 and C.22 respectively.

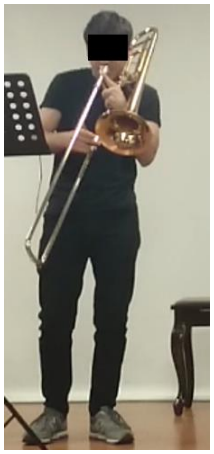


Figure 5.39. Trombone playing position

5.3.8. Evaluation of the RULA Scores for All Instruments

According to the results of the RULA analysis, playing musical instruments from different musical instrument families has different risks in terms of playing related symptoms or injuries. The viola is found the have the highest risk of playing related injuries by having a RULA score of 7 and it is followed by the trombone and the guitar which had a score of 6 from RULA analysis. Following trombone and guitar, drum playing positions got scores 4 and 5 depending on the upper limb and the playing position. The flute playing position also got a score of 4 from RULA, which points out that flute playing can have similar amount of risks as drum playing. The instruments having the least risk are found out to be piano and the keyboard for some playing positions. Piano playing was given a score of 3 and it was illustrated that the playing position and repertoire didn't change the RULA score, while keyboard playing scored 4 and 3 depending on the upper limb whether it is left or right and the playing position change.

The scores of the RULA showed that none of the playing postures of the musical instruments investigated are comfortable. Although there are different risks associated with playing instruments from different instrument families, all the playing positions should be improved to maintain more ergonomic postures. Nevertheless, the application of the

RULA was limited since all the instruments from each instrument family weren't included. Moreover, the playing position change effect could clearly be seen for some instruments such as drums and keyboard playing for right upper limb, however, for playing the piano, any change couldn't be observed between different playing positions. What's more, the investigation of the repertoire change pointed out that there is no significant risk difference for the upper limbs between the playing positions of two different musical pieces. For the other musical pieces, the dissimilarity of the playing risks might be noted if the playing positions are significantly different. A summary of the RULA results are shown in Table 5.113.

Table 5.113. Summary of RULA results

Musical Instrument	**Playing Position**	**Left Upper Limb RULA Score**	**Right Upper Limb RULA Score**	**Significant Risk Factors**
Drums	Position-1	4	5	Wrist, neck
	Position-2	5	4	Wrist, neck, upper arm
Viola	Position-1	7	7	Wrist, upper and lower arm, neck
Guitar	Position-1	6	6	Upper and lower arm, wrist, neck
Keyboard	Position-1	3	4	Upper and lower arm, wrist
	Position-2	3	3	Upper and lower arm, wrist
Piano	Position-1	3	3	Neck, trunk
	Mozart A major sonata	3	3	Wrist, neck, trunk
	Liszt D-flat major etude Position-1	3	3	Neck, trunk
	Liszt D-flat major etude Position-2	3	3	Upper and lower arm, wrist, neck, trunk
Side Flute	Position-1	4	4	Upper and lower arm, wrist, neck
Trombone	Position-1	6	6	Upper arm, wrist, neck

5.4. Musicians' Improvement Suggestions for the Musical Instrument Playing Experience and Instrument Design

The participants were asked how to improve their musical instrument playing experiences and they are requested to state their musical instrument design improvement ideas for better comfort and performance.

5.4.1. Musicians' Suggestions for Enhancing Instrument Playing Experience

Participants knew how they learned to play their instruments, what problems they encountered and how they solved them. Also, they had musculoskeletal symptoms at their body parts. Therefore, they were asked about their general ideas about improving musical instrument playing experiences. The suggestions made by the participants for better musical performance are shown in Table 5.114 and the suggestions are organized according to the topics of practicing, tools, supportive devices and seats, playing position and technique, musical performance, and others.

Table 5.114. Musicians' instrument playing experience improvement suggestions

Practicing
Practicing and resting time management
Comfort of the instrument practice place
Practice plan
Increasing exercise time
Warming up
Discipline and regular practice
Slow and regular practicing
Playing different exercises at different positions
Regular practice everyday
Having more frequent breaks and increasing the time played in a day.
Giving breaks even though you are not tired
Stretching exercises between practices and stretching after practicing
Exercise before playing
Tools, Supportive Devices and Seats
Drum seats can be on rails and slidable
Instrument strap for carrying
Ergonomic seat, lower back rest or lower back cushion
More ergonomic piano seat
Finger wrap for guitar in order to avoid pain
Usage of a wider and softer guitar strap
Darbouka strap
Playing Position and Technique
Appropriate posture while playing
Method of playing
Correct and comfortable playing position
Playing technique improvement
Better stands can help in maintaining better position
Sitting erect or adequate sitting posture while playing

Table 5.114. Musicians' instrument playing experience improvement suggestions (cont.).

Musical Performance
Shorter performances
Playing carefully not to cause too much exertion on the muscles
Playing with correct muscles
Concentrating
Reducing stress
Others
Listening different type of music
Eagerness to practice
Enhanced music education
Comfortable instrument design
Instrument specifically designed for individual
Correct adjustment of drum set and seat
Making sports regularly
Daily exercises made by the weight of the body
Different music types
Strengthening exercises
Inspiration, eagerness to practice and nice pieces/songs to play
Concentrating on learning objectives
Taking private courses from professionals
Making sports for physical condition
Yoga and Pilates
Teaching stretching, yoga, and meditation during instrument education
Better acoustics in the working environment
Motivating videos
Good music theory background
Appropriate room temperature
Appropriate hand dimensions for playing chords and octaves for piano

5.4.2. Participants' Suggestions for Musical Instrument Designs

The instrument design ideas of the participants were collected as well as their ideas about improving the instrument playing experiences. Participants' instrument design suggestions for better comfort and performance are summarized in Table 5.115. In Table 5.115, instrument design improvement suggestions are grouped according to the musical instrument families.

Table 5.115. Musicians' instrument design suggestions

Plucked Strings Group
Harp
Lighter instrument, easy to carry with pedals
Baglama
By making the neck of the baglama thinner, the grasp will be better.
The height of the strings from the neck shouldn't be too much
Usage of softer material for strings
The design of the body and neck can be inclined to backward
Bass Guitar
Thinner neck and the balance of body and neck
Lighter material, lighter instrument
Shorter neck
Short scale frets
Sensors on the guitar strap measuring the weight of the guitar can guide the musician about the weight balance
Guitar
Guitar design which can fit between legs
Adjustable guitar fretboard according to the type of music played
Smaller guitar for carrying and traveling
Usage of different tools instead of foot support
When buying a guitar, selection of a guitar with a neck comfortable for the human body or requesting a custom-made design
Simpler floating bridge systems
Guitar bridges shouldn't hurt the hand of the musician
Material use appropriate for human body
Softer strings but providing the same sound quality
Narrow, thinner or smaller guitar neck in order to ease playing and holding the instrument
Lighter guitar
The cable input area shouldn't cause discomfort to the players
Special designs for guitar neck to reduce the effort spent while playing
Guitar neck having an incline to the front side
Guitar body should be designed according to the shape of the human body
Guitar hanged by itself (There shouldn't be a need for carrying)
Neck width should be adjusted for every player
The height of the strings from the neck/fretboard should be not too much.
Softer neck
A remote-control system for the control of the sound processor pedals
Adjustable strings and neck distance
Guitar pick material that causes less discomfort for human body

Table 5.116. Musicians' instrument design suggestions (cont.).

Keyboard Group
Keyboard
Curved keyboard
Easy to carry keyboard
Piano
Piano keyboard design that is straight up to a point and then becomes elliptical.
Lighter or smaller keys
Piano keyboard can be inclined to back
Curved/Circular keyboard
Better pedal design in order to make the ankles more comfortable.
Adjustable pedal height in order to make the ankles more comfortable.
Seats with back rest
In order to hold the neck straight, a system can show where the fingers are placed on the piano
Piano pedals should be moved to inner side.
Adjustable weight of the keys by the help of a magnetic system
Strings Group
Violin
Violin having neck support
Comfortable chin and shoulder rest and can take forms according to the body
Alternative for chin and shoulder rest
Lighter instrument
Special design of violin for hand dimensions
A design for fixing violin to the body or on the shoulder
Smaller design
Viola
Lighter and smaller instrument
Drums and Percussion Group
Drums
Seats may be improved
Toms brought closer, maybe using little toms and cymbals
Easier triggered and softer foot pedals
Easy to carry: demountable percussion
Darbouka
Softer materials can be used
Darbouka with strap can be used for playing while standing
Darbouka stretching bolts can be made softer in order to avoid discomfort at leg

Table 5.116. Musicians' instrument design suggestions (cont.).

Woodwind Group
Bassoon
Design that helps to decrease the load affecting upper back and shoulders Decreasing the load on the right hand
Flute
The left hand's place on the flute can be made softer by using or covering a softer material at that area The mouth part of the flute should be closer to the inner side.
Clarinet
Lighter instrument
Oboe
Design change related with the mouthpiece
Side Flute
Flute with bended mouthpiece
Saxophone
More comfortable mouthpiece of the saxophone
Brass Group
Trombone
Changes in the mouthpiece
Trumpet
Changes for the mouthpiece, or a softer mouthpiece that makes the mouth comfortable. Lighter instrument Softer pistons

6. DISCUSSION

6.1. Discussion on the Results of the Study

In this study, the musical instrument playing related symptoms and injuries at musicians' bodies were investigated. The prevalence and performance interference of the symptoms at each body part were found out and the possible reasons affecting instrument playing related symptoms were evaluated. The results found in this study are summarized below.

6.1.1. Prevalence and Mostly Affected Body Parts

The prevalence of the musical instrument playing related symptoms at the musicians' whole body was found to be 98.28%, which means nearly all musicians experienced symptoms at least one part of their body. This explains that playing musical instruments results in symptoms at least one body part. The five mostly affected body parts according to the weighted scores from highest to lowest was found to be neck, upper back, left shoulder, lower back, and right shoulder with prevalence of 62.36%, 50%, 43.39%, 50%, and 43.68% respectively. The neck is always used during instrument playing, for instance looking to the hands while playing piano and guitar, holding the viola or violin on the body. The right and left shoulders can be considered as mostly used body parts during instrument playing which are also connected with the upper back muscles as well. Lower back muscles assist the body while sitting and standing, and they can be easily injured during lifting a load or working in an awkward posture. That's why they are one of the mostly affected body parts during instrument playing as well. Musicians' ears, which are one of the most important body parts for musicians, had a prevalence of 22.13%, which shows that musicians should use hearing protections when possible.

When the weighted scores were ordered from largest to smallest for each musical instrument group, the most affected five body parts were as the following, respectively. For the musicians playing keyboard instruments: neck, right bottom of thumb, lower back,

right thumb and left bottom of thumb, for the drums and percussion instruments players: lower back, right and left wrist, right palm and ears. For brass instruments players: mouth/lips, face/jaws, teeth, neck and right bottom of thumb. For the plucked strings instruments players: left bottom of thumb, left shoulder, left thumb, neck, and left wrist. For the strings players: neck, upper back, right and left shoulder, and left elbow. For the woodwind players: neck, right pinkie, right shoulder, mouth/lips, and right wrist. The body parts where the symptoms are mostly seen are related with the frequency of the body parts usage while playing the instruments. Moreover, the playing posture affects the playing related symptoms, for instance, drummers are sitting on a chair without back-rest while playing their instrument, that might have increased the symptoms at their related body part.

6.1.2. Musical Performance Interference

The musical performance interference, that is musicians were having symptoms and their performance were affected at a body part, were determined in the study for each body part of the musicians. The five body parts that musicians were experiencing musical performance interference were neck, lower back, upper back, left shoulder, and right shoulder with the performance interference ratios of 24.14%, 16.09%, 14.66%, 13.22%, and 13.22% respectively. The total body performance interference ratio was found to be 66.09% among all musicians. This shows when considering the 98.28% prevalence of the symptoms at whole body, musicians' performances are only interfered by some of the discomforts. Thus, it can be concluded that the musicians continue playing while they are experiencing discomfort at some body parts.

6.1.3. Instrument Group Effect

In this study, in order to investigate the effect of instrument group difference on the musical instrument playing related discomfort, the first instrument groups of the participants were taken into consideration since musicians were going to be more affected by their main instrument. The effect of playing more than one instrument was investigated and the results found is explained in the following sections.

The strings instrument players were found to have the highest number of the risky body parts with woodwind players and the strings players had the highest total body weighted scores in this study. This can be explained by the awkward body position while playing a strings instrument, especially viola or violin. Playing strings, plucked strings and woodwind instruments increased the risk of symptoms at right shoulder, which can be explained as an effect of playing positions as well.

Since every instrument from different instrument families have different playing positions, the body parts at risk changed depending on the instrument group, and playing drums and percussion, plucked strings and keyboard instruments increased the probability of having discomfort at lower back. Moreover, according to the RULA analyses, a strings group instrument got the highest score while keyboard group instruments was given the lowest score, which might clarify that the instrument playing position is related with the risks of playing related symptoms.

The reason why drums and percussion players had more discomfort at ears than the other instruments might be explained by the sound level produced while playing drums and percussion instruments and the sound exposure of ears during practice or performance.

6.1.4. Experience Effect

Increasing years of experience was found to increase the risk of ears and neck symptoms and the musical performance interference at neck. This can be explained that in long term, musicians are more affected by CTDs since their muscles used become more effected. Musicians' ability to hear is reduced in time because they encounter high amount of noise during instrument playing in many years, hence the musicians can be stated to be affected by noise exposure in longer years of instrument playing.

6.1.5. Gender Effect

Females were found to have more risks of playing related symptoms in this study. Males had lower risks of symptoms at neck and right shoulder, and performance interference at neck. This can be explained by females might state much more symptoms

they are experiencing when compared with males. However, in this study, the gender effect for all instrument groups couldn't be evaluated since female musicians were playing instruments from the strings, plucked strings, woodwind and keyboard instruments while male musicians were playing instruments from the same instrument groups as female musicians, also from brass and drums and percussion instrument groups. Hence, the gender effect for the brass and drums and percussion instruments couldn't be evaluated.

6.1.6. Hand Dimension Effect

In this study, some of the participants' both hands' hand span, thumb and index finger hand span, hand breadth, hand length, finger widths, and finger lengths were measured. After ratio scaling, the dimensions were investigated for each instrument group and checked whether dimensions of hand were correlated with the weighted scores. The hand dimensions had significant positive or negative correlations depending on the weighted score outputs. For some weighted scores, depending on the musical instrument type, hand dimensions were both significantly positively or negatively correlated with the weighted score outputs, for instance neck, right and left shoulder, right and left index finger, and right palm weighted scores. As a result of the hand dimension study, it cannot be directly stated that larger or smaller hands increases the symptoms, however, for a specific body location and a specific instrument, these conclusions can be drawn.

6.1.7. Other Effects

Musicians who were playing more than one instrument were found to have more risk of left shoulder discomfort, and performance interference at whole body, right shoulder, left shoulder, and upper back than the musicians who were playing only one instrument. The reason of why increasing the number of instruments played increased the risk of symptoms can be explained by the increased practice and performance durations of the musicians. Since musicians might use the same group of muscles while playing their instruments, this might result in CTDs.

Increasing the time of daily cell-phone use for text messaging, social media or playing games increased the risk of discomfort and performance interference of neck and

lower back. This can be explained by while using a mobile device, people tend to lean forward and sit at awkward postures, and this might have a result of symptoms while playing musical instruments. Making regular exercise each week increased the risk of having performance interference at total body. This result cannot be evaluated in a way that they directly affect musical instrument playing related disorders or not. While thinking logically, this effect can be stated as random and not important as affecting musical instrument playing related symptoms since regular exercise will increase the strength of the muscles and lower injury risk due to over-exertion unless musicians are not causing too much exhaustion on their muscles during exercises they make.

Musicians having high daily stress levels were found to be more prone to symptoms at upper back. Daily stress might have a result of stretching the muscles in daily life so much that while playing musical instruments this might cause discomfort. Increasing the weekly time spent playing increased the risk of symptoms at ears, which can be explained as increasing instrument playing increases the sound exposure, so the ears of the musicians are much more affected. Lastly, decreasing practice session duration were found to increase the risk of symptoms at neck, which can be interpreted as keeping the practice sessions short results in cooling of the muscles and so there is a higher probability of symptoms. However, it should be noted that, even though it was not found as a result of this study, longer practice sessions might result in over exertion of the muscles since after some time if the musicians don't rest their muscles, they tend to increase the strain on them. As a result, it can be stated that practice session durations should be kept at an optimum level, not too short to prevent muscle warming up, not too long to cause injuries.

6.2. Comparison with Other Studies

6.2.1. Prevalence Comparison with Other Studies

The prevalence ratios found in this study and their comparisons with other studies are shown in Table 6.1. The age and the instrument groups investigated were adjusted for each comparison. There were limited number of studies investigated the symptoms at right and left foot/ankle, hips/buttocks, right and left knee, mouth/lips, and all fingers of the right and left fingers of the hand. The total body prevalence ratio found in this study is larger

than the other studies. In the studies made so far, there were larger or smaller prevalence ratio results than this study for the body parts of neck, upper and lower back, right and left shoulder, and left and right wrist.

Table 6.1. Prevalence ratio comparison by other studies for the matched samples

Body Parts	Prevalence Ratios Found in this Study	Prevalence Ratios Found in the Other Studies
Total Body	97.58%	• 89.12%, Kok *et al.* (2013)
	100%	• 35%, León *et al.* (2015)
	100%	• 79%, Chan, *et al.* (2000)
	97.18%	• 77%, Furuya *et al.* (2006)
	98.01%	• 53%, Knapik, *et al.* (2007)
	100%	• 77%, Sandell et al. (2009)
	98.13%	• 89.7%, Plevnik *et al.* (2015)
	98.11%	• 93%, Chimenti *et al.* (2013)
	96.77%	• 64.9%, Barton *et al.* (2008)
	98.85%	• 86%, Leaver *et al.* (2011)
	100%	• 81.4%, Victor *et al.* (2016)
Neck	77.14%	• 39%, Kaufman-Cohen and Ratzon (2011)
	45.16%	• 67.06%, Mishra and Gangopadhyay (2013)
	71.74%	• 57.1%, Chan *et al.* (2000)
	67.52%	• 64.8%, Paarup *et al.* (2012)
	73.02%	• 25.5%, Nyman *et al.* (2007)
	74.58%	• 74.2%, Victor *et al.* (2016)
Upper Back	64.29%	• 42%, Kaufman-Cohen and Ratzon (2011)
	59.87%	• 53.2%, Paarup *et al.* (2012)
Left Shoulder	48.57%	• 55%, Kaufman-Cohen and Ratzon (2011)
	47.83%	• 57.1%, Chan *et al.* (2000)
	41.40%	• 52.8%, Paarup *et al.* (2012)
	49.21%	• 25.5%, Nyman *et al.* (2007)
Lower Back	19.05%	• 49%, Kaufman-Cohen and Ratzon (2011)
	80.65%	• 74.15%, Mishra and Gangopadhyay (2013)
	49.68%	• 50.5%, Paarup *et al.* (2012)
	35.59%	• 66.7%, Victor *et al.* (2016)
Right Shoulder	67.14%	• 55%, Kaufman-Cohen and Ratzon (2011)
	9.68%	• 67.06%, Mishra and Gangopadhyay (2013)
	59.32%	• 57.1%, Chan *et al.* (2000)
	52.23%	• 50.0%, Paarup *et al.* (2012)
	62.70%	• 25.5%, Nyman *et al.* (2007)
Right Wrist	45.22%	• 29.6%, Paarup *et al.* (2012)
	42.37%	• 75.3%, Victor *et al.* (2016)
Left Wrist	38.22%	• 36.1%, Paarup *et al.* (2012)
	38.98%	• 75.3%, Victor *et al.* (2016)
Left elbow	16.56%	• 24.5%, Paarup *et al.* (2012)
Right elbow	19.75%	• 19.4%, Paarup *et al.* (2012)

Table 6.1. Prevalence ratio comparison by other studies (cont.).

Body Parts	Prevalence Ratios Found in this Study	Prevalence Ratios Found in the Other Studies
Right foot/ankle	6.37%	• 22.7%, Paarup *et al.* (2012)
Hips/Buttocks	5.10%	• 18.5%, Paarup *et al.* (2012)
Left knee	4.46%	• 30.1%, Paarup *et al.* (2012)
Left foot/ankle	5.10%	• 22.7%, Paarup *et al.* (2012)
Right knee	5.73%	• 30.1%, Paarup *et al.* (2012)
Right & Left Thumb	42.25% & 26.76%	• 38.2%, Furuya *et al.* (2006)
Right & Left Index Finger	8.45% & 8.45%	• 14.1%, Furuya *et al.* (2006)
Right & Left Middle Finger	7.04% & 9.86%	• 24.1%, Furuya *et al.* (2006)
Right & Left Ring Finger	5.63% & 7.04%	• 24.8%, Furuya *et al.* (2006)
Right & Left Pinkie	11.27% & 12.68%	• 38.2%, Furuya *et al.* (2006)
Mouth/Lips	20.69%	• 20.1%, Altenmüller *et al.* (2012)

6.2.2. Musical Performance Interference Comparison with Other Studies

The comparison of the performance interference ratios with the other studies in Table 6.2 points out that only one study investigated the musical performance interference of the playing related symptoms or disorders, moreover, the study which investigated the musical performance interference only covered the total body interference. As a result of this study, musicians' all body parts' musical performance interference values were calculated, which is a new information for the literature.

Table 6.2. Performance interference ratio comparison by other studies

Body Parts	Musical Performance Interference Ratios Found in this Study	Musical Performance Interference Ratios Found in the Other Studies
Total Body	66.09%*	• 30%, Ranelli *et al.* (2011)

* The ratio was not adjusted for age since the comparison study was made on children (age:7-17 years)

6.2.2. Comparison of Factors Affecting Playing Related Symptoms with Other Studies

6.3.2.1. Instrument Type. When the results of this study and other studies are compared for the factors affecting musical instrument playing related symptoms, common and contradictory findings were found out. In this study, the instrument group was found as an important factor affecting the playing related symptoms as stated as a result in the studies made by Ranelli *et al* (2011), Barton *et al.* (2008), Kim *et al*. (2012), Russo *et al.* (2013), and Pawlaczyk-Łuszczyńska *et al*. (2011). Moreover, it was found that the playing related symptom locations were changing according to the instrument group, which was also stated in the study made by León *et al*. (2015).

In this study, the instrument group found to have the highest risk for total body weighted score was strings instruments. The RULA analyses also showed the same results. However, for every weighted score output, different instruments were found to have different risks, for instance, plucked strings instruments were considered as risky for left wrist while woodwind instruments were risky for mouth/lips. Zaza and Farewell (1997) found out that string players have more risks of being injured, which can be considered as a common finding with this study. Gambichler *et al*. (2008) expressed that musicians who are playing instruments from strings and plucked strings group had higher risk of playing related symptoms. For the total body weighted scores, strings was the only instrument found to be risky in our study, hence, for plucked strings instruments, it can be stated that it is riskier when compared with other instruments for some body parts such as shoulders, upper back, and left bottom of thumb.

Furhermore, brass, guitar and woodwind players were found to have more risks of musculoskeletal discomfort than the other instruments in the study made by Altenmüller *et al*. (2012). Woodwind players were found to have more risks of right shoulders than the other instrument in this study, which can be considered as a common finding. However, guiar and woodwind players were not found to have more risks than other instuments. In the study made by Paarup *et al*. (2011), woodwind players were found to have less probability of having musical instrument playing relayed injuries, which is a conflicting finding with this study.

6.3.2.2. Experience. In this study, years of playing experience was found affecting musical instrument playing symptoms, which can be considered as a common finding with the studies made by Zaza and Farewell (1997), Pawlaczyk-Łuszczyńska *et al*. (2011), and Gambichler *et al*. (2008). However, in the study made by Victor *et al.* (2016), years of playing wasn't found to have an effect on playing related disorders, which is contradictory to the findings of this study.

6.3.2.3. Gender. The results of this study pointed out that females had more risky body parts than males for strings and keyboard instruments. Moreover, male musicians were found to have lower probability of neck and right shoulder discomfort and performance interference at left shoulder. From these results, it can be concluded that gender had an effect on musical instrument playing related discomfort, which is a common finding as it is in the studies made by Ranelli *et al*. (2011), Paarup, *et al*. (2011), Altenmüller *et al*. (2012), and Barton *et al*. (2008).

Furhermore, Zaza and Farewell (1997), Fjellman-Wiklund and Edling (2009), Árnason *et al*. (2014), and Ranelli *et al*. (2008) stated that female musicians have more risk of playing related discomfort than male musicians, which can be considered as a similar result since the results of the study showed that females had more for symptoms and performance interferences. Altenmüller, Baur, Hofmann, Lim, and Jabusch, (2012) stated that male musicians have higher risks of instrument playing related injuries, which is a conflicting finding with this study.

6.3.2.4. Hand Dimensions. The hand dimensions' correlations with weighted scores were studied for every instrument group and the hand size effect was summarized for every weighted score output. As a result, it was found out that hand size is positively or negatively correlated with different outputs. Lai, *et al.* (2015) and Sakai *et al*. (2006) stated that hand span was found to have an effect on the risk of musicians' injures, which is a similar result found in this study. De Smet *et al*. (1998) stated that smaller hands had more risk of instrument playing related injuries, which cannot be stated as a similar result since in this study it was shown that for many different outputs, both smaller and hands were found to be risky. Linari-Melfi *et al*. (2011) stated that pianists who have neck pain have smaller hands than the pianists who don't have neck pain and according to the results of

our study, smaller hands resulted in larger weighted scores at neck, which can be considered as a parallel result. Moreover, Furuya *et al*. (2006) stated that hand size wasn't a contributing factor to musical instrument playing disorders, however, in this study hand dimensions were found to be correlated with the discomfort at the body parts.

6.3.2.5. Other Factors. The results of this study showed that playing more than one instrument increased the risk or symptoms which is as stated by Victor *et al*. (2016). However, De Smet *et al*. (1998) couldn't find any relation between number of instruments played and musculoskeletal disorders of the musicians, thus, this can be considered as a conflicting factor. Daily cell phone use time wasn't found at any study as an affecting factor for playing related symptoms.

In order to evaluate the effect of stress on the musical instrument playing related symptoms, musicians' daily and musical performance stress levels were investigated in this study. High daily stress level was found to increase the risk of symptoms at lower back, which can be considered as a common finding with the study made by Furuya *et al*. (2006). Moreover, Zaza and Farewell (1997) stated that nervousness in daily life was an important factor on playing related disorders and it was also stated by Rickert *et al*. (2013), Sandell *et al*. (2009), and Victor *et al*. (2016) that stress was associated with instrument playing related injuries, which is also a common finding with this study.

Weekly playing time was found to increase symptom risk at ears in this study, which can be considered as a parallel solution as in the studies made by Kaufman-Cohen and Ratzon (2011), Gohil *et al*. (2016), and Gambichler *et al*. (2008), in which weekly playing hours were stated to affected instrument playing related disorders.

6.3. Prevention Ideas for Musical Instrument Playing Related Discomfort and Injuries

In order to prevent symptoms and injuries as a result of musical instrument playing, musicians should be adviced for taking precautions for instrument playing. In this section, this study's prevention suggestions for musical instrument playing positions and instrument designs are explained.

6.3.1. Recommendations for Each Instrument Group Players

6.3.1.1. Keyboard Instruments Players. The musicians who were playing musical instruments from the keyboard group were found to have symptoms mostly at neck, lower back, right thumb, and right and left bottom of thumb. Pianists, keyboardists and other keyboard group instrument players should follow the suggestions below in order to prevent musculoskeletal discomfort during playing.

(i) For piano and keyboard/organ playing, if the instrument is being played at sitting position, the seat should be adjusted properly in order to keep the arms straight and maintain the appropriate playing height. The arms should be parallel to the floor and the body should be kept straight while playing the instrument, this will prevent the discomfort at lower back, neck, wrists and fingers. Moreover, a chair with a lower back support might help sitting at an appropriate posture.

(ii) During the playing of piano and keyboard/organ instruments while sitting, if there is a need for playing at the lower or upper octaves for some time, leaning on one side should be avoided, changing the position on the seat might be preferred, otherwise leaning should be kept at minimum level.

(iii) In order to avoid awkward positions of the hand, the correct fingers should be used while playing, the numbering of the fingers for each note should be studied before practice or performance in order to prevent playing related symptoms, especially for the most challenging part of the musical piece. This will lower the adduction angles at the wrists and keep the fingers and the hands close to the neutral position.

(iv) The force distribution onto the fingers and the wrists should be balanced, the wrists should be kept straight and adduction at wrist should be avoided as much as possible especially when chords and octaves are being played. The fingers shouldn’t be stretched too much in order to avoid the excessive amount of stress on the finger muscles.

(v) During keyboard playing while standing, the body should be kept straight and close to neutral posture as much as possible. The stands of the keyboards should be adjusted for the playing position, the correct and most comfortable incline angles should be used while using two or three keyboards on the stand. For sitting

during playing keyboard, a high-sit stand can be useful for playing more than one keyboards.

(vi) Using a hearing protection during the orchestra or band rehearsals in a music studio is highly recommended, it will be better to use protective headphones from which every instrument in the orchestra or band can be heard. Hearing the music played while keeping the sound level under the dangerous limits will increase the musical experience.

(vii) The muscles used for playing the instrument should be kept in condition, if musicians haven't played their instrument for a long time, precautions should be taken at the first time of playing after a long time. Excessive amount of force exertion should be avoided and practice durations should be kept short for a while until the hand and body is adapted for playing the instrument again.

(viii) Even though the instrument is played every day, it is recommended to warm-up and make quick stretching exercises before playing, and make stretching exercises after the playing. This will warm-up the muscles, keep them relaxed and decrease the probability of being injured during playing.

6.3.1.2. Plucked Strings Instruments Players. The plucked strings players among the participants had symptoms mostly at left bottom of thumb, left shoulder, left thumb, neck, and left wrist. For the prevention of the symptoms, it is advised for the musicians to follow the below stated suggestions.

(i) When sitting and playing the guitar, the body should be straight and close to neutral posture, balanced, and supported from legs and feet. A cushion or a supportive tool can be used in order to elevate the guitar and keep the body straight. Also, a sit-stand could help avoiding playing related discomfort.

(ii) Hands' movements are important for the health of the muscles. The hand that is used to make rhythms, arpeggios and to use the guitar pick, which is mostly the right hand, should be relaxed and kept straight as much as possible. While making arpeggios, the wrist and the arm should be straight and the fingers shouldn't be stressed too much. When the guitar is played fast, e.g., playing Flamenco, the wrist and arms' straight posture shouldn't be changed, wrist shouldn't be used in the movements that result in adduction of wrists.

(iii) When using guitar pick during playing, the movement of the right hand should be minimized and only sufficient force should be applied on the strings. There is no doubt that depending on the music type played high repetition can occur, however, the force applied to the guitar pick should be kept at minimum as much as possible.

(iv) For the hand that is used to play notes, chords, and riffs on the guitar neck, which is the left hand in most cases, over-exertion of the muscles should be avoided. The notes should be played with the minimum force required in order to remove the unnecessary load acting on muscles, and while playing barre chords, the thumb shouldn't be stretched too much, it should be relaxed but providing balance to the guitar.

(v) If possible, the plucked strings instruments with an appropriate neck thickness and width for hand dimensions should be selected.

(vi) For the playing position while standing, comfortable straps with an appropriate width should be used. Giving breaks when possible to rest your lower back is important while playing while standing. During performances, in order to avoid leaning and adjusting the pedal and processor sounds, select a processor or pedal set that has the capability of saving presets so that the sounds can be changed by foot without leaning. If there is no opportunity than changing the sounds by hand, it is better to place the guitar or the instrument played somewhere else and then make the adjustments.

(vii) While playing the harp, it is important to adjust the instrument height and position depending on its size. An object can be used to set the height and maintain stability. The body posture should be kept close to the neutral posture as much as possible and the neck should be kept straight during playing.

(viii) Use of a hearing protection during practicing with band or performance is recommended.

(ix) Warming-up before playing and making stretching exercises before and after playing will reduce the risk of playing related symptoms or injuries.

6.3.1.3. Strings Instruments Players. The musicians playing strings instruments had symptoms mostly at neck, upper back, right shoulder, left shoulder, and left elbow. Moreover, strings instruments were found to have the highest number of risky body parts

among all instrument groups. In order to prevent discomfort, it is advised for the musicians to follow the suggestions below.

(i) While holding the violin or viola on the shoulder, the instrument should be supported by a method of playing posture in which the chest, shoulder, the side of the neck, and jaws are used rather than using the chin. This will result in a head position of looking forward and prevent stressed neck muscles.

(ii) When using the bow, musicians tend to make pinching, which results in a stressed thumb, however, if thumb is used in a bent and relaxed position, movements of the arm and the wrist can be made easily and comfortably.

(iii) The placement of the fingers on the neck of the instrument is essential, it is recommended to place the fingers comfortably, to do that, the ring finger or the little finger can be placed on the neck of the instrument firstly and then the other fingers will be referenced from these fingers.

(iv) When playing the cello, the musicians should sit straight and balanced with legs. The instrument should be played by maintaining the straight position of the neck as much as possible. Using a seat with a back support might be useful in order to prevent discomfort during instrument playing.

(v) While using the bow during cello playing, adduction or abduction of wrist movements should be prevented.

(vi) Warming-up and stretching exercises are highly recommended for strings instruments. Stretching before and after playing is important for relaxing the tense muscles.

6.3.1.4. Drums and Percussion Instrument Players. Participants playing drums and percussion instruments had symptoms mostly at lower back, right wrist, left wrist, right palm and ears. In order to prevent symptoms, musicians should follow the suggestions below.

(i) While playing drums, since most of the seats don’t have back support, musicians should sit straight to prevent lower back injuries. This will also protect lower back while playing the kick pedal.

(ii) Playing the kick pedal needs the force at the muscles to be maintained for a long time. Therefore, ankles shouldn't be used while playing the kick pedal and the force should be supplied from the thigh muscles. In case of using double kick pedals, the distance between both pedals should be well adjusted according to the players' comfortable playing position.

(iii) Hi-hat should be at a place where the drummer will not need to twist his or her body to play. Moreover, the pedal of the hi-hat should be at a comfortable position so that it can easily be played simultaneously with the kick pedal.

(iv) While holding the stick, the hand shouldn't be stressed too much but maintaining a balanced force on the stick. The stick should be held basically by the thumb and the index finger without exerting too much force, and the middle, ring and the little finger should support holding and movements during playing.

(v) The drums should be played with the wrists' and arms' flexion and extension movements. The adduction or abduction of the wrist should be avoided while playing.

(vi) During the playing of percussion while standing, the straight body posture should be maintained. Leaning on left or right sides for changing percussions should be avoided. Moreover, the adduction and abduction of the hand wrists should be avoided, flexion and extension movements of the arm and wrist should be preferred.

(vii) While playing darbouka, musicians should sit straight, hold the instrument without exerting too much force but making it fixed to the body. Using inside of the hand and avoiding adduction and abduction of the wrists are recommended.

(viii) Hearing protection during the rehearsals or musical performance, should be used in order to prevent hearing loss.

(ix) For drummers, making sports without injuring muscles are recommended for increasing the strength and the endurance of the muscles of the body.

(x) What's more, warming up before playing and stretching before and after playing is highly recommended.

6.3.1.5. Woodwind Instruments Players. The body parts which the woodwind players mostly had discomfort was neck, right pinkie, right shoulder, mouth/lips, and right wrist.

The suggestions which are stated below should be followed in order to prevent symptoms during instrument playing.

(i) While playing the side flute, musicians should keep their neck straight and hold the instrument balanced without exerting too much force by hands. The instrument should be balanced by using the lips and index finger and thumb of the left and right hand respectively.

(ii) Musicians shouldn't play the side flute while their thumbs are under stress, the hands and the fingers should be relaxed but they should maintain the balance of the instrument.

(iii) As soon as the side flute playing finishes during a rehearsal or concert, musicians should return to the normal posture and hold the flute at the side of their body while waiting for their time for playing.

(iv) The wrists of the musicians should be straight and adduction and abduction movements shouldn't be made between the wrists and arms.

(v) For the clarinet, saxophone and flute playing, the instrument shouldn't be held in a position while the muscles are tight. The neck and the whole body should be kept straight.

(vi) For all woodwind instruments, it is necessary to give frequent breaks while practicing in order to give time for the lips, mouth and other muscles to relax.

(vii) If it is possible, selecting a woodwind instrument that requires less energy to be spent during playing is preferred.

6.3.1.6. Brass Instruments Players. Brass players had discomfort mostly at their mouth/lips, face/jaws, teeth, neck, and right bottom of thumb. For the brass players, the suggestions which are stated below should be followed in order to prevent symptoms during instrument playing.

(i) While playing the trumpet, the right hand should be relaxed while pushing the pistons, this can be maintained by putting the right finger on the little finger hook rather than placing the finger inside the hook.

(ii) Trumpet should be held while the angle between the left hand and wrist are minimized as much as possible to prevent adduction at the wrist.

(iii) While playing the trumpet, the neck should be kept straight in order to prevent discomfort at neck.

(iv) During the playing of the instrument with an orchestra, it is recommended to return to neutral posture when the part of the musical piece that brass instruments are needed ends, waiting in the neutral posture will relax the body muscles.

(v) When playing the trombone, musicians tend to tilt their neck forward. This posture should be avoided and the neutral posture should be maintained in the body.

(vi) Trombone holding posture requires lifting and balancing the instrument. Musicians shouldn't over stretch their hand muscles and hold the instrument; the left index finger should be under the mouthpiece of the instrument and support the balance from that position.

(vii) Giving frequent breaks while playing a brass instrument is important since musicians will experience discomfort at the lips after playing. To prevent the discomfort at lips, it is necessary to give breaks and hold the instrument stable by the hands, therefore, reduced amount of weight will affect the lips.

6.3.1.7. General Recommendations. The general recommendations given for all instruments groups are listed below.

(i) Musicians should be aware of playing related injuries while playing their instruments.

(ii) Any supportive tool such as seat with a lower back support or a comfortable violin cushion during playing should be used for better performance and injury prevention.

(iii) Musicians should listen to their body, and they shouldn't over-exert their muscles during instrument playing to prevent disorders.

(iv) Fresh-starter musicians should improve themselves by making regular instrument playing exercises. Resting is important for during practicing, thus when learning a new musical piece body muscles should be rested in order to avoid musculoskeletal disorders.

(v) Musicians should be well-trained for instrument playing. If a musical instrument wasn't played for a long time, warming-up exercises should be made and playing time should be increased gradually.

(vi) Warming-up should be made always before starting to play an instrument. Stretching exercises can help for warming-up muscles.

(vii) In case of severe symptoms during practice, playing should be stopped and the muscles should be rested for a while.

(viii) Since ears are important body parts for the musicians, hearing protectors should be used during practicing with a band or orchestra.

6.3.2. Prevention Ideas with Ergonomic Instrument and Supportive Tool Design

6.3.2.1. Ergonomic Piano and Keyboard Design Suggestion. For reducing the abduction angles of the wrists while playing the piano or the keyboard, a slight curve is given to the keyboard after the approximate shoulder length and the ergonomic piano/keyboard were formed. In Figure 6.1, the ergonomic piano and keyboard design suggestion is shown. The keys' angle is gradually increasing, the first angle difference is set to be 3° and the sides of the piano has 10° angle.

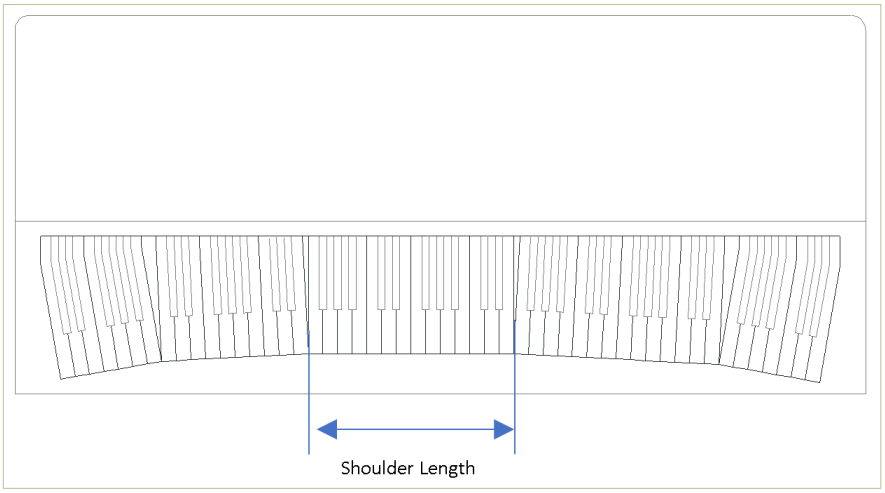


Figure 6.1. Ergonomic piano and keyboard suggestion

6.3.2.2. Adjustable guitar holder. The usage of guitar straps cause load on the muscles of a guitarist while playing during the standing position in concerts or rehearsals. By using the

adjustable guitar holder shown in Figure 6.2, the load on the muscles will be removed. The adjustable guitar holder will be suitable in order to use with any guitar since it has adjustment knobs so that the angles and the length of the carrier arms can be changed.

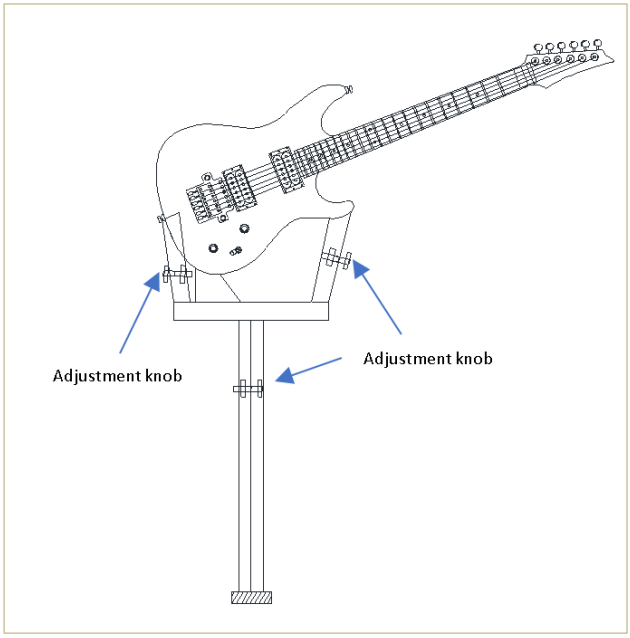


Figure 6.2. Adjustable guitar holder

6.3.2.3. Flute with Bended Mouthpiece. In order to ease the side flute playing, the bended mouth shape flute can be used. It will provide an instrument playing position close to the neutral posture and reduce the discomfort at shoulders, neck and wrists.

Figure 6.3. Flute with bended mouthpiece

7. CONCLUSIONS

In this study, information was collected from the participants through questionnaire, hand dimension measurement, and photos taken during instrument playing. The aim of the study was to investigate the factors affecting musical instrument playing related symptoms, to find out the prevalence and performance interferences of musical instrument playing related discomfort, to analyze the playing positions of each instrument group, to point out the effect of hand dimensions on the musicians' symptoms, and to make preventive suggestions for playing related discomfort.

According to the results of the study, the conclusions drawn are explained as the following:

(i) The prevalence of the musical instrument playing related symptoms were found to be high at whole body with the ratio of 98.28%, and the most affected five body parts which were neck, upper back, left shoulder, lower back, and right shoulder had prevalence of 62.36%, 50%, 43.39%, 50% and 43.68%, respectively. Moreover, ears of the musicians had symptom prevalence of 22.13%.

(ii) The musical performance interference ratios found at neck, lower back, upper back, left shoulder, and right shoulder were 24.14%, 16.09%, 14.66%, 13.22% and 13.22%, respectively, and the performance interference at the whole body of the musicians were found as 66.09%.

(iii) Musicians' playing related symptoms were stated to be changing according to the musical instrument groups. Strings and woodwind group instruments had the highest number of risky body parts to be affected by musical instrument playing related discomfort.

(iv) The musicians having higher experience levels were found out to have more risky body parts and higher rate of symptoms.

(v) Hand dimensions were significantly positively or negatively correlated with the weighted scores depending on the instrument group.

(vi) Musicians who were playing more than one instrument were found to have more risk than the musicians playing one instrument

(vii) Increase in the daily time spent using mobile phones for text-messaging, social media or playing games increased the risk of discomfort.

(viii) Having high daily stress levels increased the probability of having symptoms at upper back.

(ix) Increase in the weekly time spent playing the musical instrument increased the risk of having discomfort at ears.

(x) The viola, which is an instrument from strings family, had the highest MSD risk with respect to RULA evaluation while the piano, a keyboard family instrument, had the lowest score.

(xi) The suggestions related with playing positions and precautionary habits were made for each musical instrument group.

(xii) The suggestions related to playing positions and precautionary habits were made for each musical instrument group.

(xiii) The developed survey tool can be used for collecting information from musicians' symptoms.

7.1. Limitations of the Study

In the study, information was collected by the developed questionnaire, thus, the data were based on the subjective evaluations of the participants. Moreover, the hand dimensions were taken from a limited number of participants and the dimensions were scaled to the other population members who don't have hand dimensions measured, which was an approximation and the actual values of every participants' hand dimensions might point out different results. What's more, in order to evaluate the MSD risk of instrument playing positions, the RULA technique was applied in this study. However, RULA doesn't investigate the details of the hand such as the finger positions and exerted finger forces.

7.2. Recommendations for Further Research

Since hands are one of the most used body parts of the musicians, another method examining the hands in detail including fingers and palms can be used besides RULA. The musicians' body motion can be investigated in detail for each instrument by recording videos so that better prevention ideas can be made. Moreover, the force applied on the musical instruments during playing can be measured by sensors, so the amount of force required for playing each instrument can be recorded and improvements can be made accordingly. Last but not least, for ergonomic instrument designs, after the designs are made and prototype instruments are manufactured, musicians' performance can be tested and the body motions with the force applied on them can be evaluated.

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APPENDIX A: MUSICIANS' SYMPTOM SURVEY

(Adapted from Ekşioğlu, 2017)

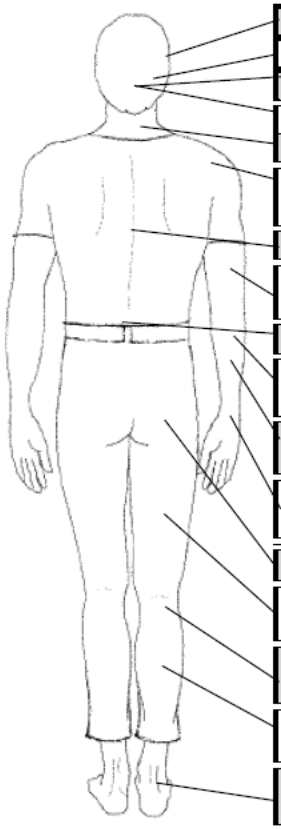
A.1. Musicians' Symptom Survey

Part 1. In this part, you will answer questions related with your personal attributes, daily life, musical instrument usage, music related disorders and instrument design preferences.

Age:_____	Gender: □M □F	Height: _____	Weight:_____	City of family origin: _____
Hand Dominance: □Left □Right □Either			Occupation: _____	
Smoking: □Yes □ No If yes, how many packages per day? _____				
Alcohol: □Yes □ No If yes, how many times per week? _____				
How many hours do you sleep on average each day? _____				
Do you regularly exercise each week (including walking)? □Yes □No				
Main instrument played:_____ Average time spent for playing in a week_____				
Second instrument played:_____ Average time spent for playing in a week_____				
Main instrument years of playing:_____			Second instrument years of playing:_____	
On average, how long do you play in each practice session without a break? _____ On average, how long does a rest break last? _____				
Do you warm-up before start practicing? □Yes □ No				
Type(s) of music you play:_____				
Have you ever received injury preventive music education? □Yes □No				
1a) Do you have any previous musculoskeletal injury (e.g., hand, wrist, back, neck, ear)? □Yes □ No If yes, was it music related? □Yes □ No			1b) What type of injury (please specify)? _____ Did you receive any treatment? □Yes □ No	
1c) If injury was music related, what do you think was the cause of the injury?			1d) In your opinion, how that injury could be avoided?	
2a) During instrument playing, do you feel, ache, pain, numbness or any other physical discomfort in any part of the body? □Yes □No			2b) If yes, type of discomfort(s)? 1. 2. 3. 4.	
3a) Please state your stress level in your daily life. (1-low, 5-high) □1 □2 □3 □4 □5			3b) Please state your stress level during musical performance (1-low, 5-high) □1 □2 □3 □4 □5	
4a) On average, how many hours do you use a computer in a day? _____			4b) On average, how many hours on a day do you use your cell-phone to text message, use social media, surf internet etc.? _____	
5a) What could improve your musical instrument playing experience? (e.g., instrument design related, use method related, time related) 1._____ 2._____ 3._____			5b) For comfort and higher performance, what kind of design changes do you want to see in your main instrument? (e.g., circular piano, flute with bended mouth piece etc.)	

Figure A.1. Musicians' symptom survey Part-1

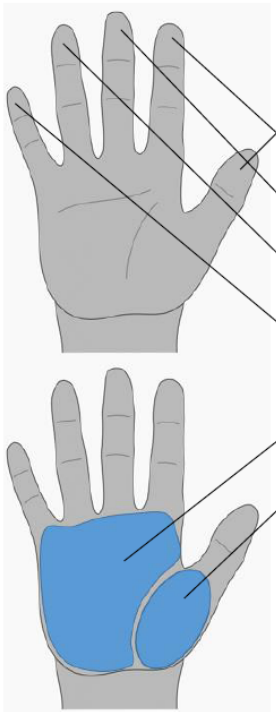
Part 2. The diagram below shows the approximate position of the body parts referred to in the questionnaire. Please answer by marking the appropriate box.



		FREQUENCY During the last week of instrument playing, how often did you experience ache, pain and/or discomfort for the indicated body parts?					SEVERITY If you experienced ache, pain and/or discomfort, how uncomfortable was this?			PERFORMANCE If you experienced ache, pain and/or discomfort, did this interfere with your music performance?		
		Never	1-2 times	3-4 times	Once every day	Several times every day	Slightly uncomfortable	Moderately uncomfortable	Very uncomfortable	Not at all	Slightly interfered	Substantially interfered
Ears		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Face/Jaws		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Mouth/Lips		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Teeth		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Neck		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Shoulder	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Upper back		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Upper arm	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Lower back		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Elbow	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Forearm	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Wrist	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Hips/Buttocks		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Thigh	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Knee	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Lower leg	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Foot /Ankle	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Figure A.2. Musicians' symptom survey Part-2

Part 3. The diagram below shows the approximate position of the hand parts (excluding wrist) referred to in the questionnaire. Please answer by marking the appropriate box.



		FREQUENCY During the last week of instrument playing, how often did you experience ache, pain and/or discomfort for the indicated body parts?					SEVERITY If you experienced ache, pain and/or discomfort, how uncomfortable was this?			PERFORMANCE If you experienced ache, pain and/or discomfort, did this interfere with your music performance?		
		Never	1-2 times	3-4 times	Once every day	Several times every day	Slightly uncomfortable	Moderately uncomfortable	Very uncomfortable	Not at all	Slightly interfered	Substantially interfered
Thumb	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Index Finger	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Middle Finger	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Ring Finger	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Pinkie	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Palm	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Bottom of thumb	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Figure A.3. Musicians' symptom survey Part-3

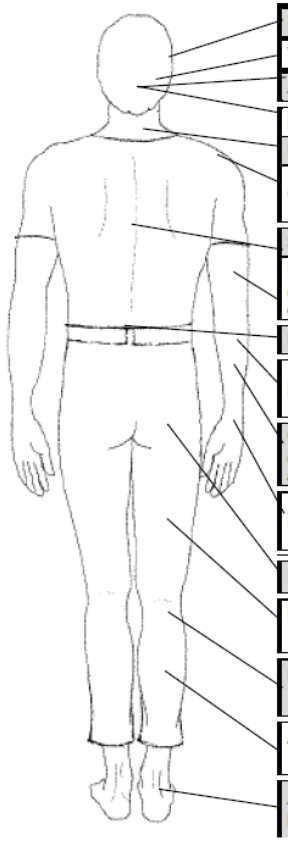
A.2. Müzisyen Semptom Anketi

1. Bölüm. Bu bölümde, kişisel özellikleriniz, günlük yaşantınız, müzik aleti kullanımınız, müzisyen rahatsızlıkları ve müzik aleti tasarımı hakkındaki soruları yanıtlayacaksınız.

Yaş:_____	Cinsiyet: □E □K	Boy: _____	Kilo:_____	Memleketiniz: _____
Baskın El: □Sol □Sağ □İkisi de			Mesleğiniz: _____	
Sigara kullanımı: □Evet □ Hayır Kullanıyorsanız, günde kaç paket içiyorsunuz?_____				
Alkol kullanımı: □Evet □ Hayır Kullanıyorsanız, haftada kaç kez içiyorsunuz?_____				
Her gün ortalama kaç saat uyuyorsunuz? _____				
Her hafta (yürüme dahil) düzenli egzersiz yapıyor musunuz? □Evet □ Hayır				
Çalınan ana enstrüman:_____ Haftada ortalama çalınan süre _____(saat)				
Çalınan ikinci enstrüman:_____ Haftada ortalama çalınan süre _____(saat)				
Kaç senedir ana enstrümanınızı çalıyorsunuz?_____			Kaç senedir ikinci enstrümanınızı çalıyorsunuz?_____	
Enstrümanınızla çalışırken ortalama ne kadar süre ara vermeden çalarsınız? _____ İki çalışma seansı arası ortalama ne kadar dinlenirsiniz? _____				
Enstrümanınızla çalışmaya başlamadan önce ısınma hareketleri yapar mısınız? □Evet □ Hayır				
Çaldığınız müzik tarz(lar)ı:_____				
Daha önce hiç müzisyen hastalıklarını önleyici eğitim aldınız mı? □Evet □Hayır				
1a) Daha önceden incinme veya sakatlık geçirdiniz mi? (örnek: el, bilek, sırt, boyun, kulak vs. bölgelerinde) □Evet □ Hayır Eğer geçirdiyseniz, müzik ile ilgisi var mıydı? □Evet □ Hayır			1b) Ne tarz bir incinme veya sakatlık geçirdiniz (Lütfen tanımlayınız)? _____ Tedavi aldınız mı? □Evet □ Hayır	
1c) Eğer incinme veya sakatlık müzik ile ilgiliyse, nedeni sizce neydi?			1d) Sizce bu incinme veya sakatlık nasıl önlenebilirdi?	
2a) Müzik aleti çalarken vücudunuzun herhangi bir yerinde sızlama, acı, uyuşma veya başka fiziksel rahatsızlıklar hissediyor musunuz? □Evet □ Hayır			2b) Hissediyorsanız, hangi tür rahatsızlıklar hissettiğiniz belirtiniz? 1. 2. 3. 4.	
3a) Lütfen günlük yaşamdaki stres seviyenizi belirtiniz. (1-düşük, 5-yüksek) □1 □2 □3 □4 □5			3b) Lütfen müzikal bir performans sırasındaki stres seviyenizi belirtiniz (1-düşük, 5-yüksek) □1 □2 □3 □4 □5	
4a) Bir günde ortalama kaç saat bilgisayar kullanıyorsunuz? _____			4b) Günde ortalama kaç saat mesajlaşmak, sosyal medyayı takip etmek veya internette gezmek vb. için cep telefonu kullanıyorsunuz?	
5a) Sizce müzik aleti çalma deneyiminiz nasıl iyileştirebilir? (Örnek: enstrümanın farklı tasarımı, farklı bir yöntemle çalma, çalma ve dinlenme sürelerinin düzeni, vb.) 1._____ 2._____ 3._____			5b) Ana müzik aletinizi çalarken daha yüksek konfor ve performans elde etmek için, müzik aleti tasarımında nasıl bir değişiklik olmasını isterdiniz? (Örnek: yarı-eliptik piyano, flüt ağzının bükülmüş olması vb.)	

Figure A.4. Müzisyen semptom anketi Bölüm-1

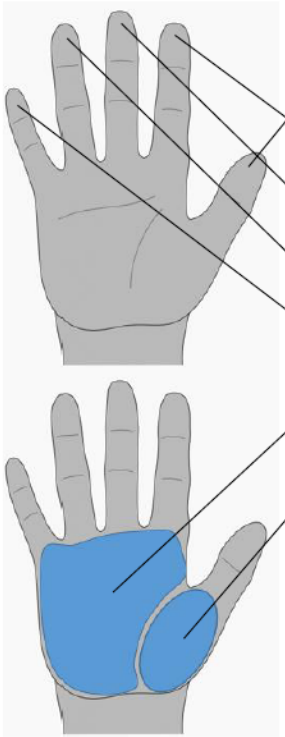
2. Bölüm. Aşağıdaki resim, ankette sorulan vücut bölümlerini yaklaşık olarak göstermektedir. Lütfen uygun kutucuğu işaretleyerek cevaplayınız.



		FREKANS Enstrüman çalmakla meşgul olduğunuz son hafta içinde, vücudunuzun aşağıda gösterilen bölümlerinde ne sıklıkla ağrı, sızı ve/veya rahatsızlık hissettiniz?					ŞİDDET Eğer ağrı, sızı ve/veya rahatsızlık hissettiyseniz, ne kadar şiddetliydi?			PERFORMANS Eğer ağrı, sızı ve/veya rahatsızlık hissettiyseniz, bu müzik performansınızı etkiledi mi?		
		Hiç hissetmedim	Hafta boyunca 1-2 kez	Hafta boyunca 3-4 kez	Her gün 1 defa	Her gün birkaç defa	Hafif şiddetliydi	Orta şiddetliydi	Çok şiddetliydi	Hiç engel olmadı	Biraz engel oldu	Çok engel oldu
Kulaklar		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Yüz/Çeneler		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Ağız/Dudaklar		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Dişler		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Boyun		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Omuz	(Sağ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Sol)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Sırt		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Üst Kol (Omuz-dirsek arası)	(Sağ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Sol)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Bel		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Dirsek	(Sağ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Sol)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Önkol (Dirsek-bilek arası)	(Sağ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Sol)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Bilek	(Sağ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Sol)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Kalça		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Üst Bacak	(Sağ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Sol)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Diz	(Sağ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Sol)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Alt Bacak	(Sağ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Sol)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Ayak ve bileği	(Sağ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Sol)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Figure A.5. Müzisyen semptom anketi Bölüm-2

3. Bölüm. Aşağıdaki resim, ankette sorulan el bölümlerini (bilek hariç) yaklaşık olarak göstermektedir. Lütfen uygun kutucuğu işaretleyerek cevaplayınız.



		FREKANS Enstrüman çalmakla meşgul olduğunuz son hafta içinde, vücudunuzun aşağıda gösterilen bölümlerinde ne sıklıkla ağrı, sızı ve/veya rahatsızlık hissettiniz?					ŞİDDET Eğer ağrı, sızı ve/veya rahatsızlık hissettiyseniz, ne kadar şiddetliydi?			PERFORMANS Eğer ağrı, sızı ve/veya rahatsızlık hissettiyseniz, bu müzik performansınızı etkiledi mi?		
		Hiç hissetmedim	Hafta boyunca 1-2 kez	Hafta boyunca 3-4 kez	Her gün 1 defa	Her gün birkaç defa	Hafif şiddetliydi	Orta şiddetliydi	Çok şiddetliydi	Hiç engel olmadı	Biraz engel oldu	Çok engel oldu
Baş parmak	(Sağ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Sol)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
İşaret parmağı	(Sağ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Sol)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Orta parmak	(Sağ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Sol)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Yüzük parmağı	(Sağ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Sol)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Serçe parmak	(Sağ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Sol)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
El ayası	(Sağ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Sol)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Başparmak alt bölgesi	(Sağ)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Sol)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Figure A.6. Müzisyen semptom anketi Bölüm-3

APPENDIX B: PARTICIPANT INFORMATION CONSENT FORM

B.1. Participant Information Consent Form

MUSCULOSKELETAL SYMPTOMS AMONG MUSICIANS: INDIVIDUAL AND INSTRUMENT-USE RELATED FACTORS

PARTICIPANT INFORMATION CONSENT FORM

Name of the study: Musculoskeletal symptoms among musicians: Individual and instrument-use related factors and interference with musical performance
Study performed by: Prof. Mahmut Ekşioğlu
E-mail address: mahmut.eksioglu@boun.edu.tr
Telephone number: 0212 359 6483

Study summary: During a musical performance, the notes on the musical instruments should be played at the correct time, the rhythm should be tracked well and the emotion in the musical piece should be expressed. While musicians are concentrated on these factors, they might play their instruments without being cautious about over-exerting their muscles and playing in awkward postures. Moreover, musical instruments were not design ergonomically to prevent musicians from injuring themselves. In order to investigate the risk and prevalence of musculoskeletal symptoms of musicians and to investigate the factors affecting the musical instrument playing related discomfort and injuries, there is a need for a study.

There is no constraint for being a participant in this study unless you play a musical instrument. The questions that will be asked to you request your information such as your age, occupation, daily musical instrument practice details, stress level during musical instrument playing etc. What's more, your suggestions for improvement of musical instrument playing conditions and design of instruments are requested. The approximate completion of this survey is 10 minutes. If the participants request to see the result of the study, it will be shared with them.

Approval: We kindly invite you to participate our study about musical instrument playing related discomfort and the factors affecting discomfort and injuries. If you want to participate this study, you will be requested to fill in the survey form which will take 10 minutes. Your name will be kept confidential.

Before signing this form, please kindly ask any questions you have. You can ask your questions to Prof. Mahmut Ekşioğlu (Tel: 0090 212 359 64 83) later as well.

I understood the information told before and I took one copy of this consent form.
I accept to participate to this study.

Participant Name, Surname and Signature Date

Participant Custodian Name, Surname and Signature Date

Figure B.1. Participant information consent form

B.2. Katılımcı Onam Formu

MÜZİSYENLERDEKİ KAS-İSKELET SİSTEMİ HASTALIKLARINDA ETKİLİ OLAN FAKTÖRLERİN İNCELENMESİ

KATILIMCI BİLGİ ve ONAM FORMU

Araştırmanın adı: Müzisyenlerdeki kas-iskelet sistemi hastalıklarının müzik aleti kullanımı, müzik performansı ve diğer faktörler ile ilişkisi
Proje yürütücüsü: Prof. Dr. Mahmut Ekşioğlu
E-mail adresi: mahmut.eksioglu@boun.edu.tr
Telefonu: 0212 359 6483

Proje konusu: Müzik aletlerinde iyi bir müzikal performans için notaların doğru anda ve istenilen ritimde çalınması, parçanın ritminin takip edilmesi ve eserdeki duygunun çalma işlemi ile bütünleştirilerek dinleyiciye aktarılabilmesi gerekmektedir. Performans sırasında bütün bunlara odaklanan müzisyenlerin bedensel sağlıklarına zarar verebilme ihtimali olan müzik aleti çalma pozisyonu, hızı ve çalma esnasında uygulanan kuvvet gibi etkenlere gerekli özeni göstermeme olasılığı bulunmaktadır. Bununla beraber, müzik aletleri de müzisyenlerin kas ve iskelet sistemi hastalıklarının engellenmesi amacıyla ergonomik biçimde tasarlanmamıştır. Türkiye'deki müzisyenlerdeki riski belirlemek, müzisyen hastalıklarına etki edebilecek faktörleri geniş çapta değerlendirebilmek ve müzisyenler arasında kas-iskelet sistemi hastalıklarının yaygınlığını araştırmak için bir çalışmaya ihtiyaç duyulmaktadır.

Bu çalışmaya katılabilmeniz için herhangi bir müzik aletini çalabiliyor olma dışında bir engel bulunmamaktadır. Çalışmada size sunulacak anketlerdeki sorularda yaşınız, mesleğiniz gibi soruların yanında müzik aleti kullanım miktarınız, günlük yaşamda ve müzikal performans sırasındaki stres seviyeniz, sağlığınıza etki edebilecek faktörler ve müzik aleti tasarımı konusundaki fikirleriniz gibi sorular bulunmaktadır. Doldurmakta olacağınız anketi tamamlama süresi yaklaşık 10 dakika sürmektedir. Çalışma sonucunda elde edilen sonuçlar kişi isterse kendisi ile de paylaşılacaktır.

Onay: Müzisyenlerdeki kas-iskelet sistemi hastalıklarının müzik aleti kullanımı, müzik performansı ve diğer etkenlerle ilişkisinin araştırılması amacıyla yapmak istediğimiz araştırmaya katılmaya sizi davet ediyoruz.

Bu çalışma kapsamında müzik ile uğraşan kişilerdeki kas-iskelet sistemi hastalıklarına etki eden faktörleri araştırarak hastalıkların müzik aleti, yaş grubu, enstrüman çalma miktarı ve diğer verilere bağlı yaygınlığı araştırılmaktadır. Araştırmaya katılmayı kabul ettiğiniz takdirde ortalama 10 dakika sürecek anketi doldurmanız istenecektir. Araştırmada isminiz gizli tutulacaktır.

Bu formu imzalamadan önce, çalışmayla ilgili sorularınız varsa lütfen sorunuz. Daha sonra sorunuz olursa, Prof. Dr. Mahmut Ekşioğlu 'ya (Tel: 0212 359 6483) sorabilirsiniz. Araştırmayla ilgili haklarınız konusunda yerel etik kurullarına da danışabilirsiniz.

Bana anlatılanları ve yukarıda yazılanları anladım. Bu formun bir kopyasını aldım.
Çalışmaya katılmayı kabul ediyorum.

Katılımcı ismi ve imzası Tarih

Varsa, Katılımcının vasisinin adı, soyadı Tarih

Figure B.2. Katılımcı onam formu

APPENDIX C: RULA EVALUATION WORKSHEETS

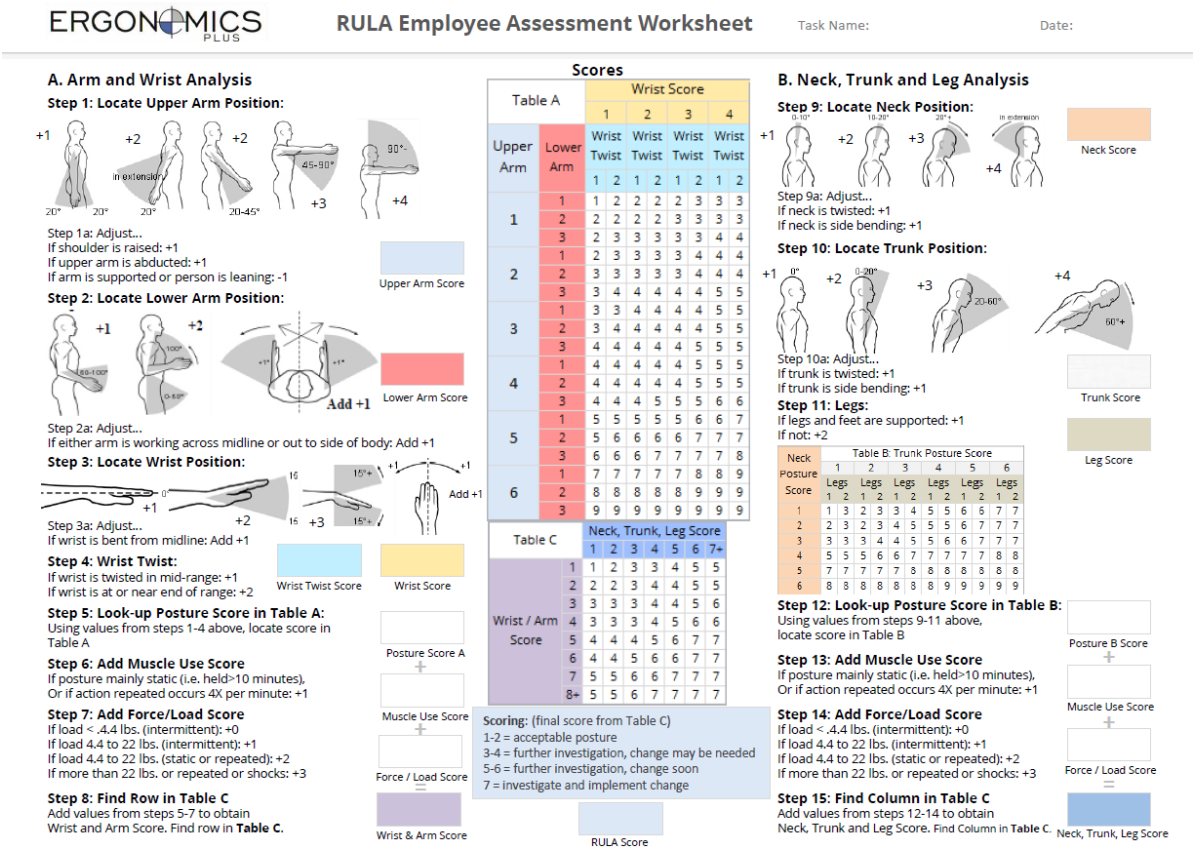


Figure C.1. Rapid Upper Limb Assessment (RULA) evaluation worksheet (Ergonomics Plus, n.d.).

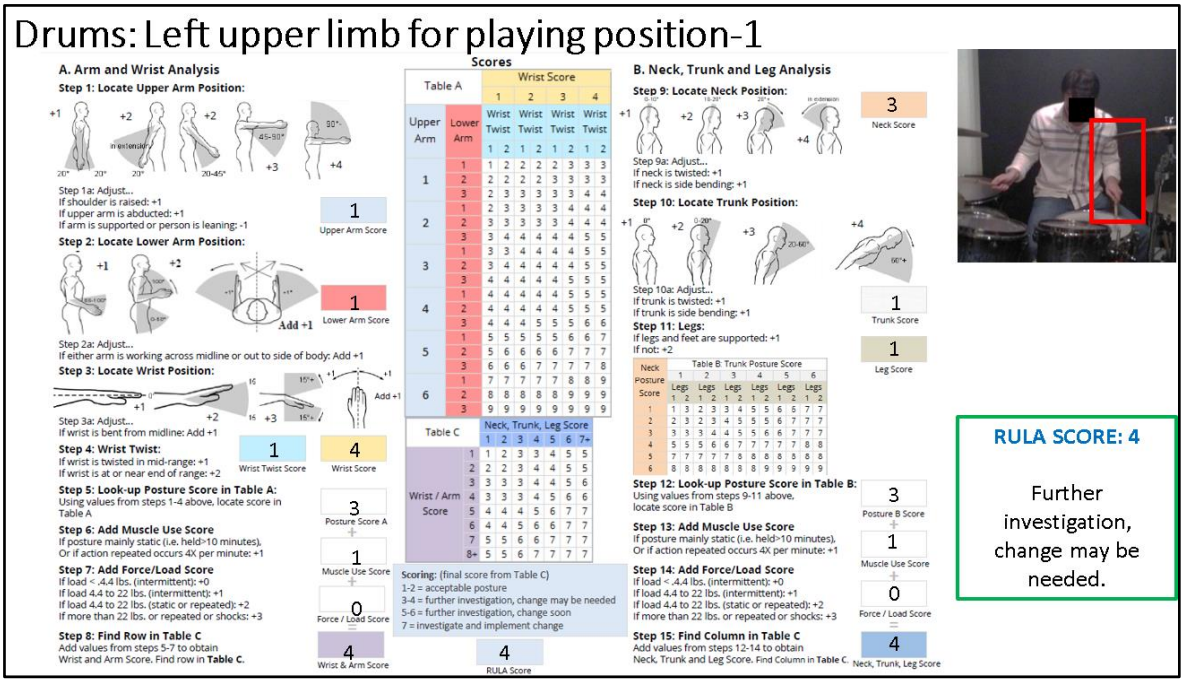


Figure C.2. RULA evaluation for drums: Left upper limb for playing position-1

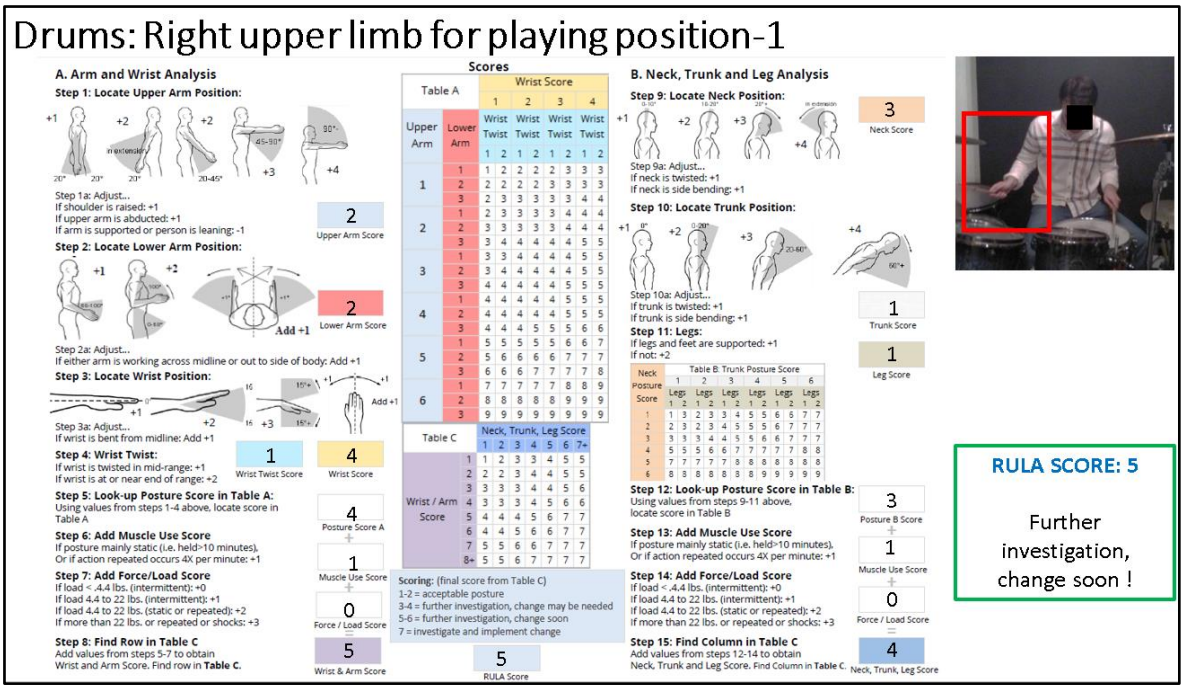


Figure C.3. RULA evaluation for drums: Right upper limb for playing position-1

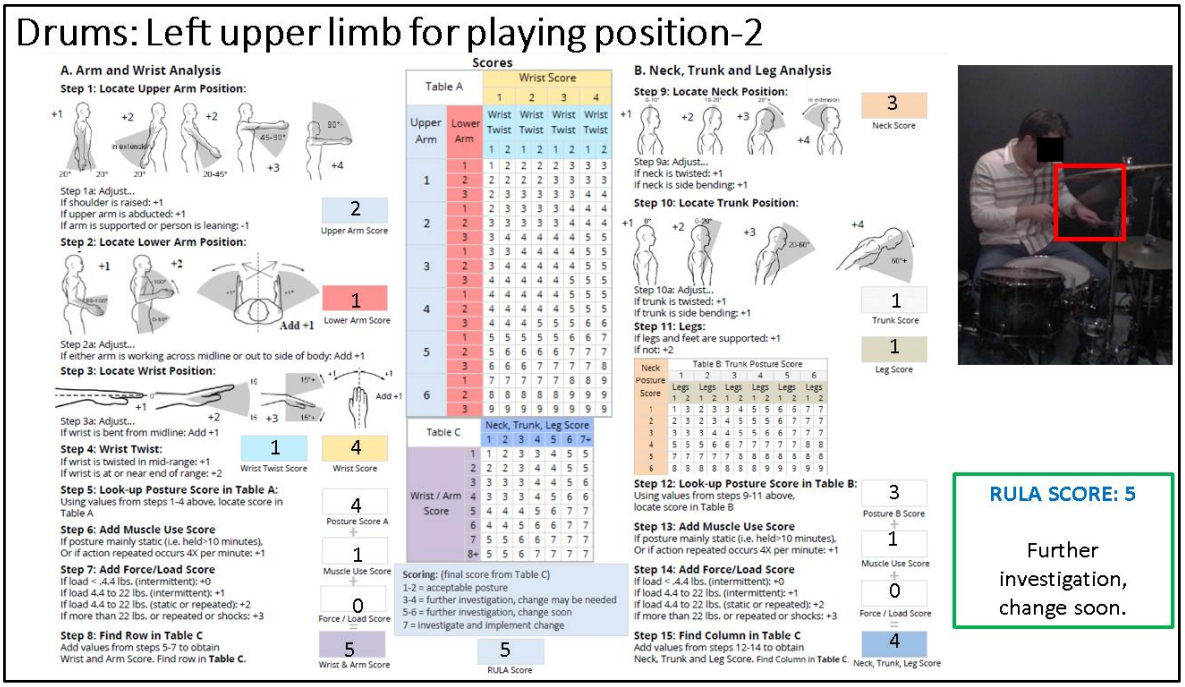


Figure C.4. RULA evaluation for drums: Left upper limb for playing position-2

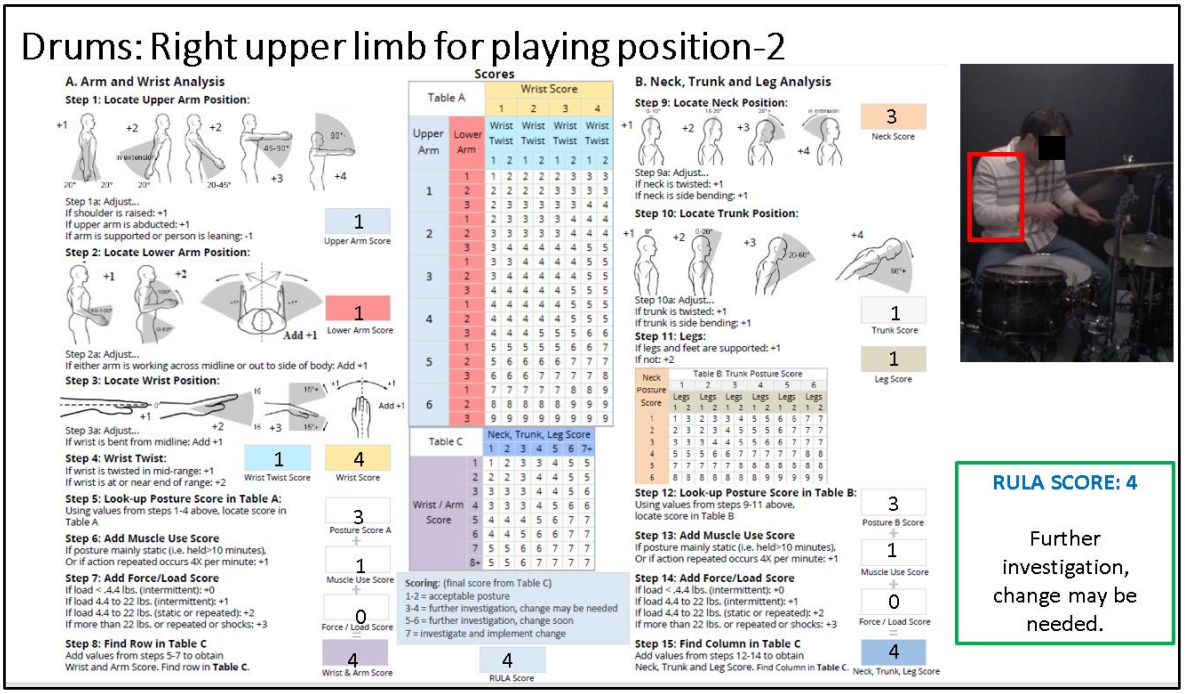


Figure C.5. RULA evaluation for drums: Right upper limb for playing position-2

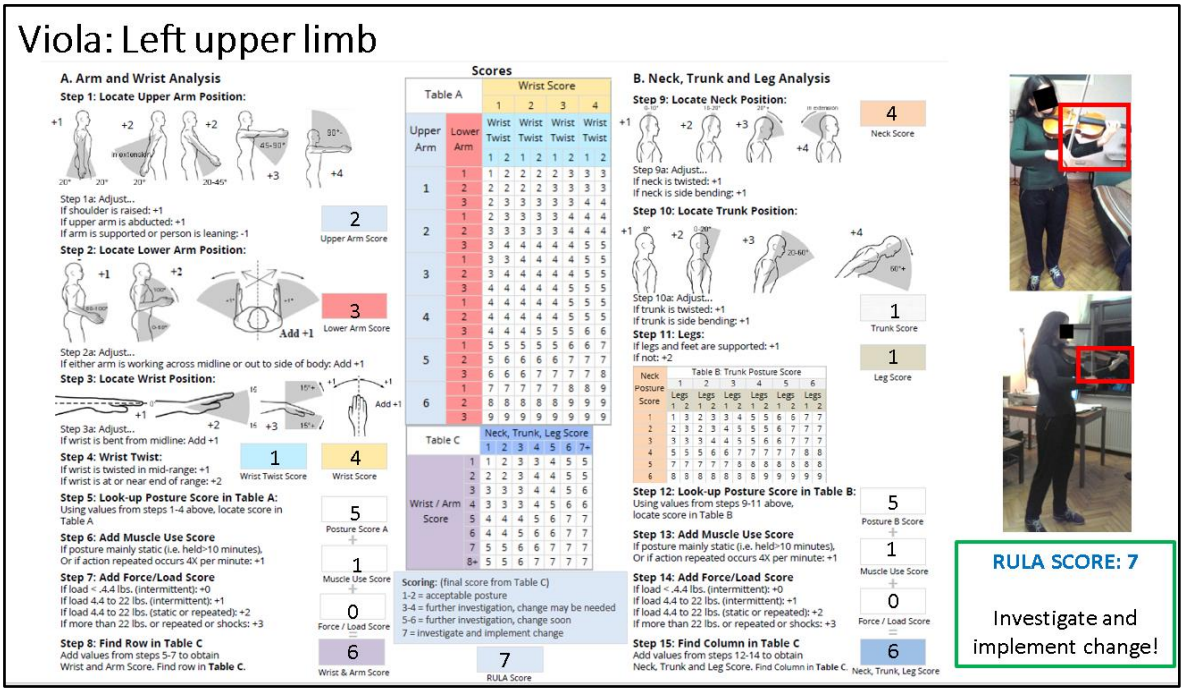


Figure C.6. RULA evaluation for viola: Left upper limb

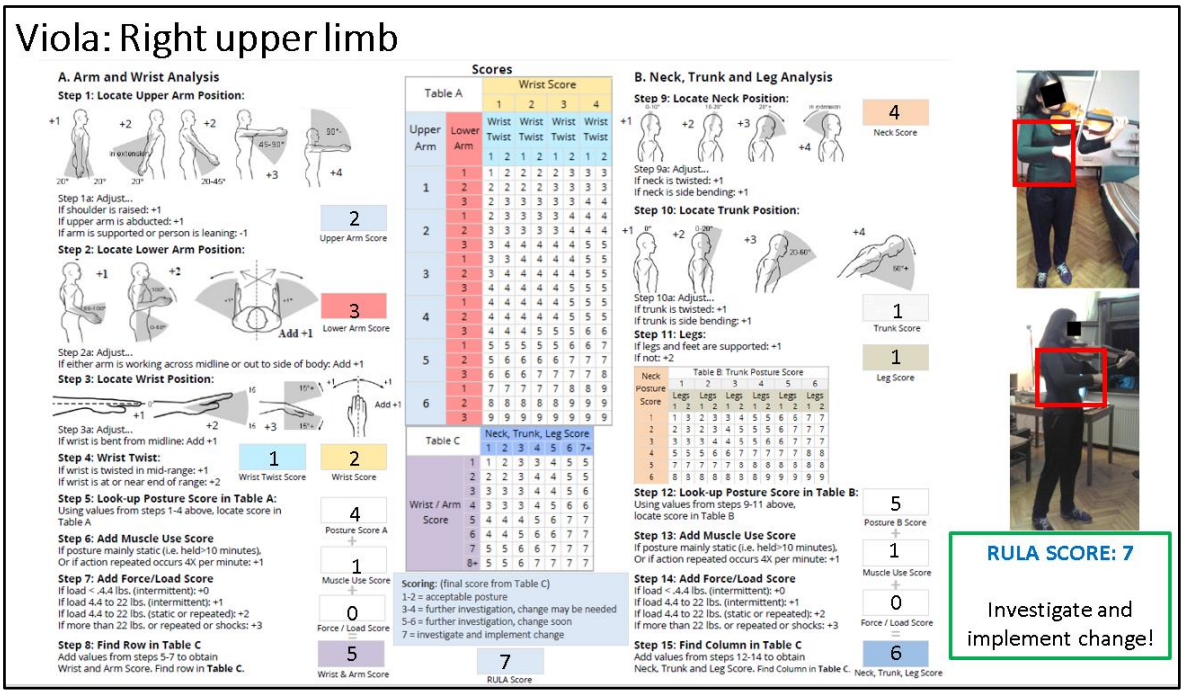


Figure C.7. RULA evaluation for viola: Right upper limb

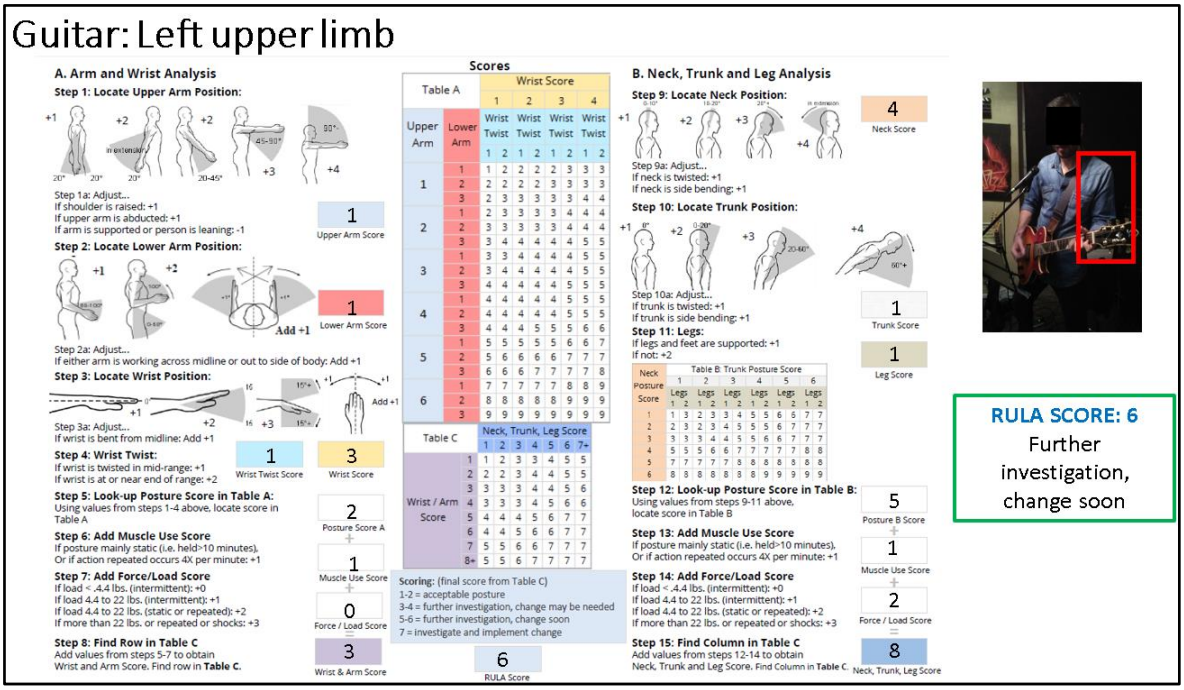


Figure C.8. RULA evaluation for guitar: Left upper limb

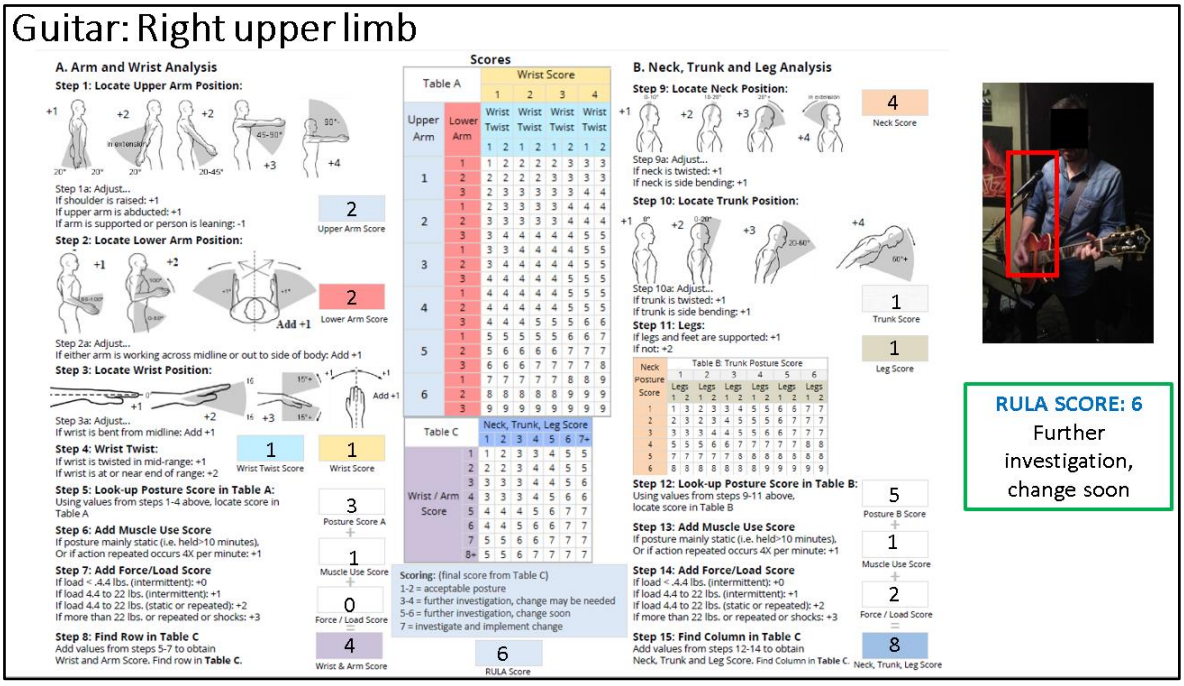


Figure C.9. RULA evaluation for guitar: Right upper limb

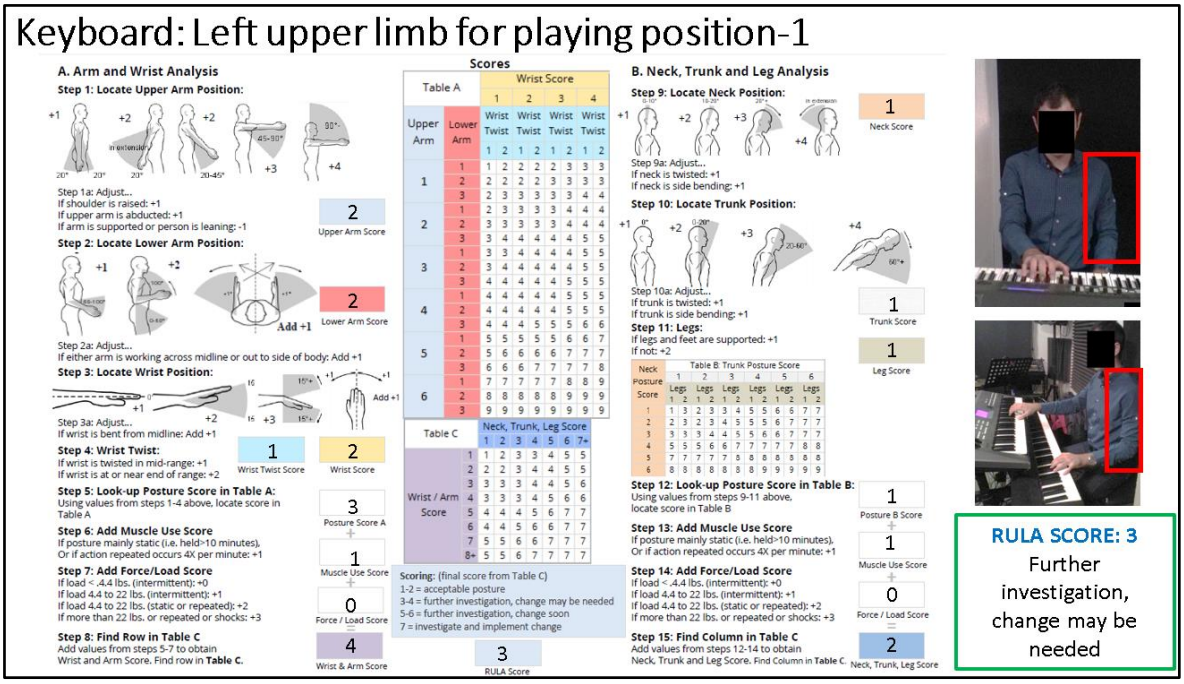


Figure C.10. RULA evaluation for keyboard: Left upper limb for playing position-1

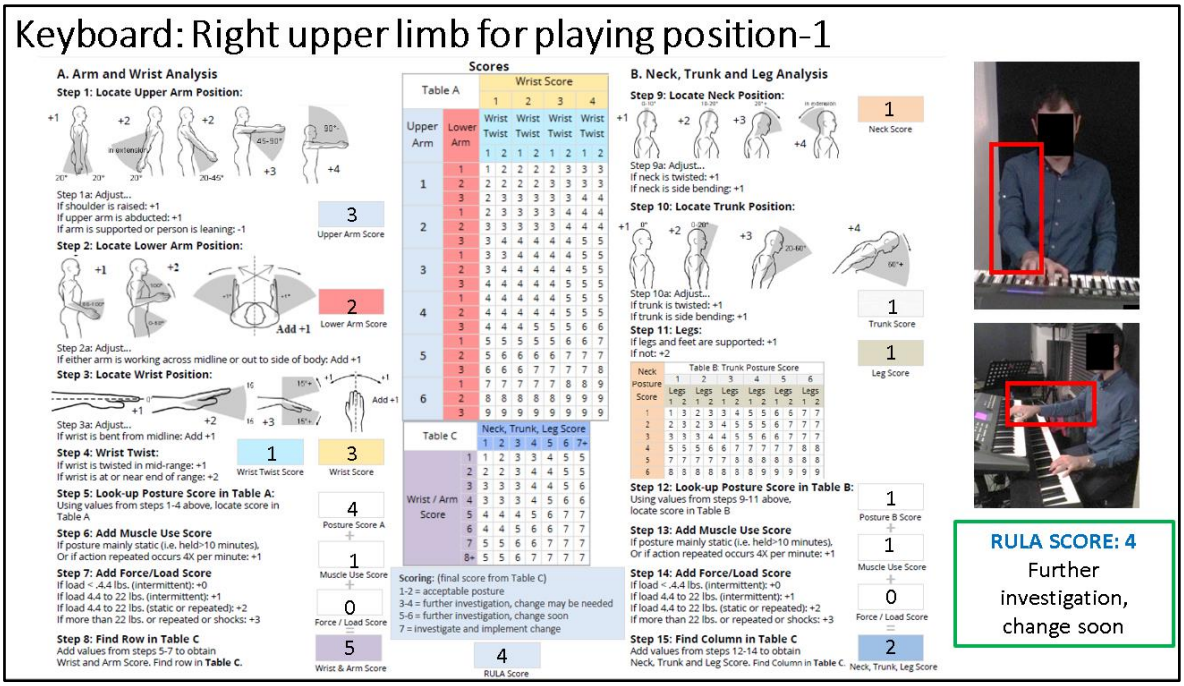


Figure C.11. RULA evaluation for keyboard: Right upper limb for playing position-1

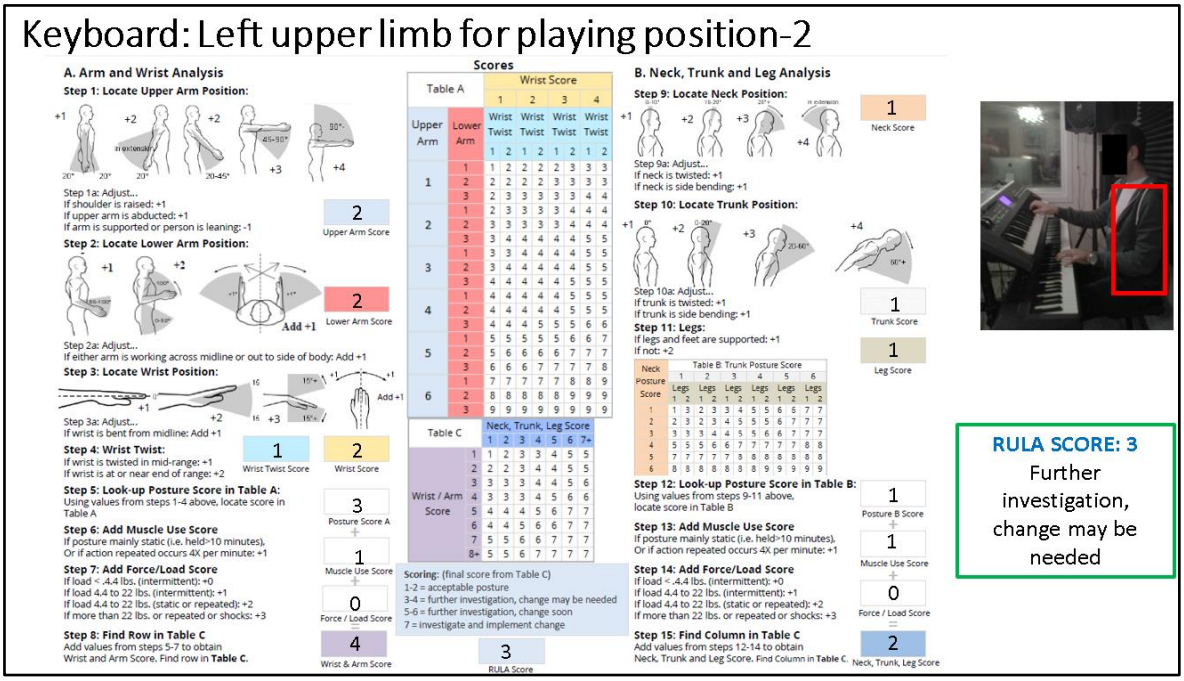


Figure C.12. RULA evaluation for keyboard: Left upper limb for playing position-2

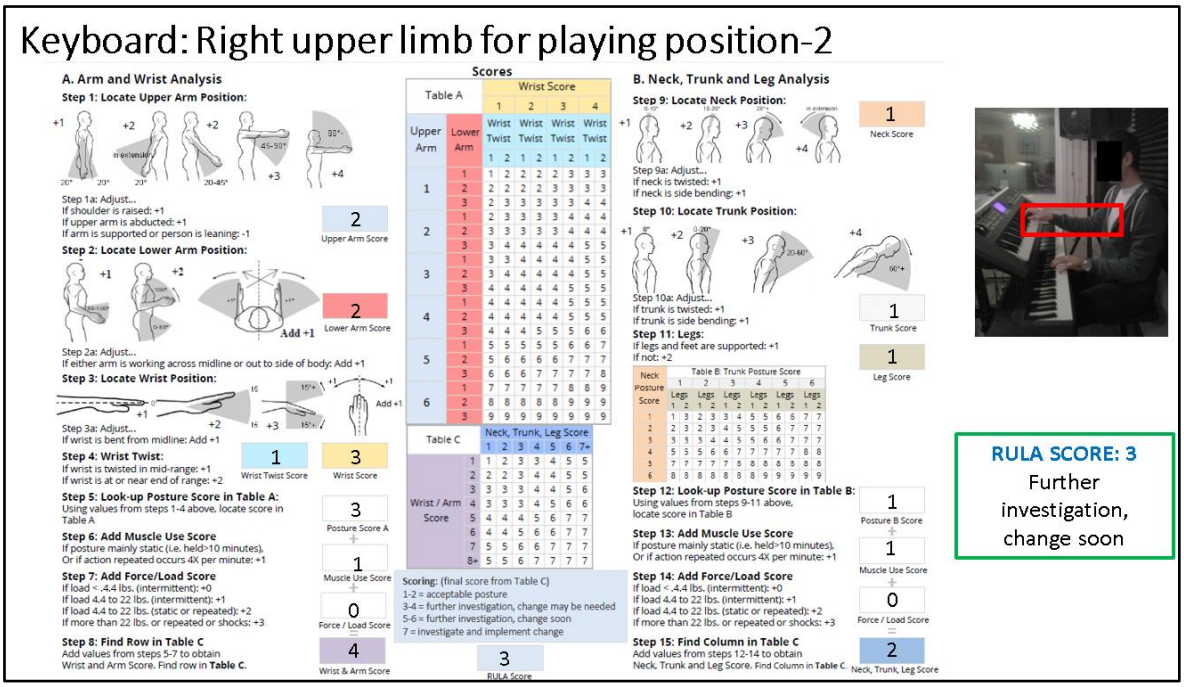


Figure C.13. RULA evaluation for keyboard: Right upper limb for playing position-2

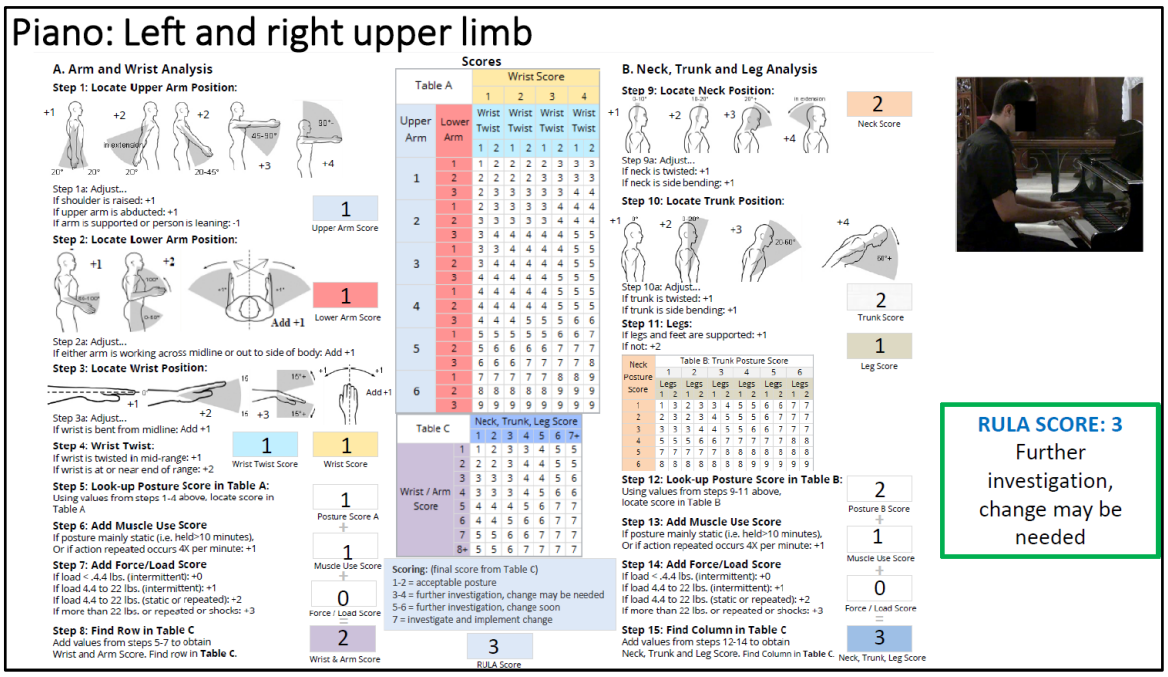


Figure C.14. RULA evaluation for piano: Left and right upper limb

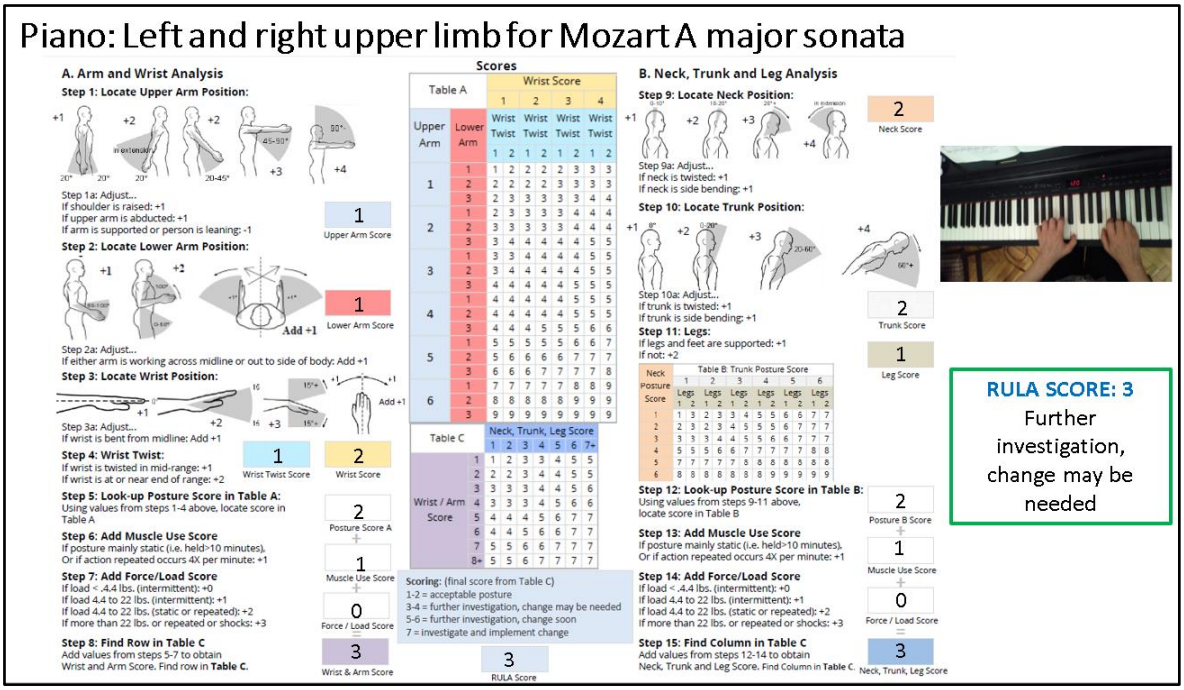


Figure C.15. RULA evaluation for piano: Left and right upper limb for Mozart A Major Sonata

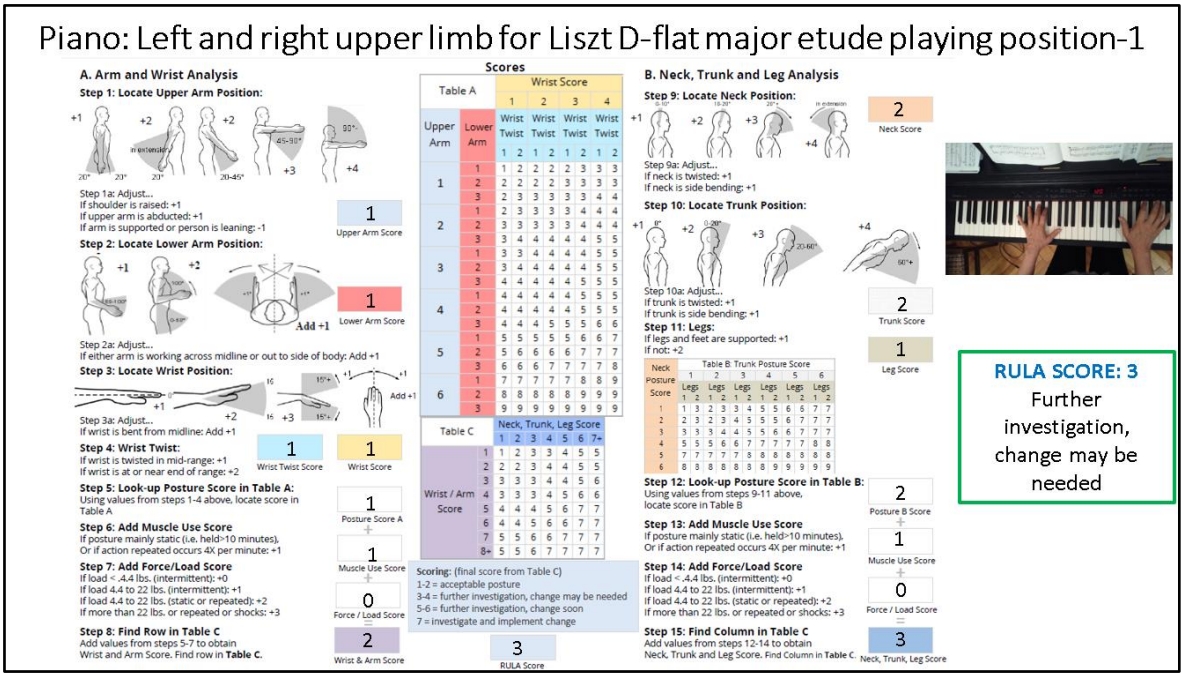


Figure C.16. RULA evaluation for piano: Left and right upper limb for Liszt D-flat major etude playing position-1

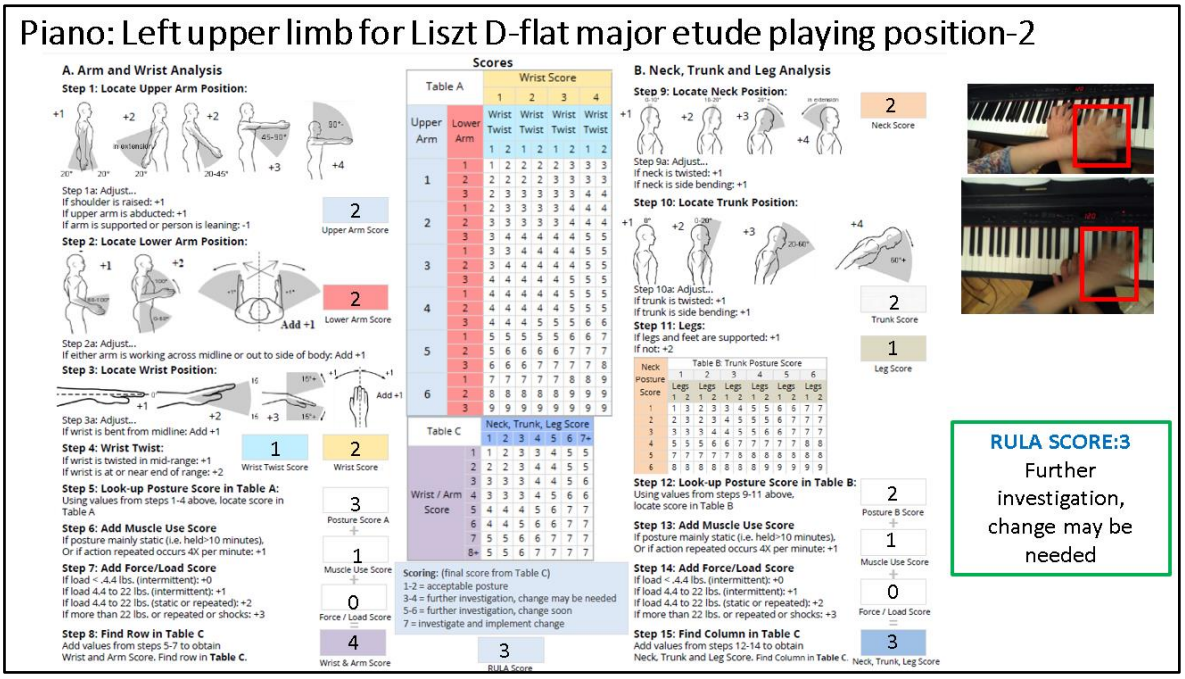


Figure C.17. RULA evaluation for piano: Left upper limb for Liszt D-flat major etude playing position-2

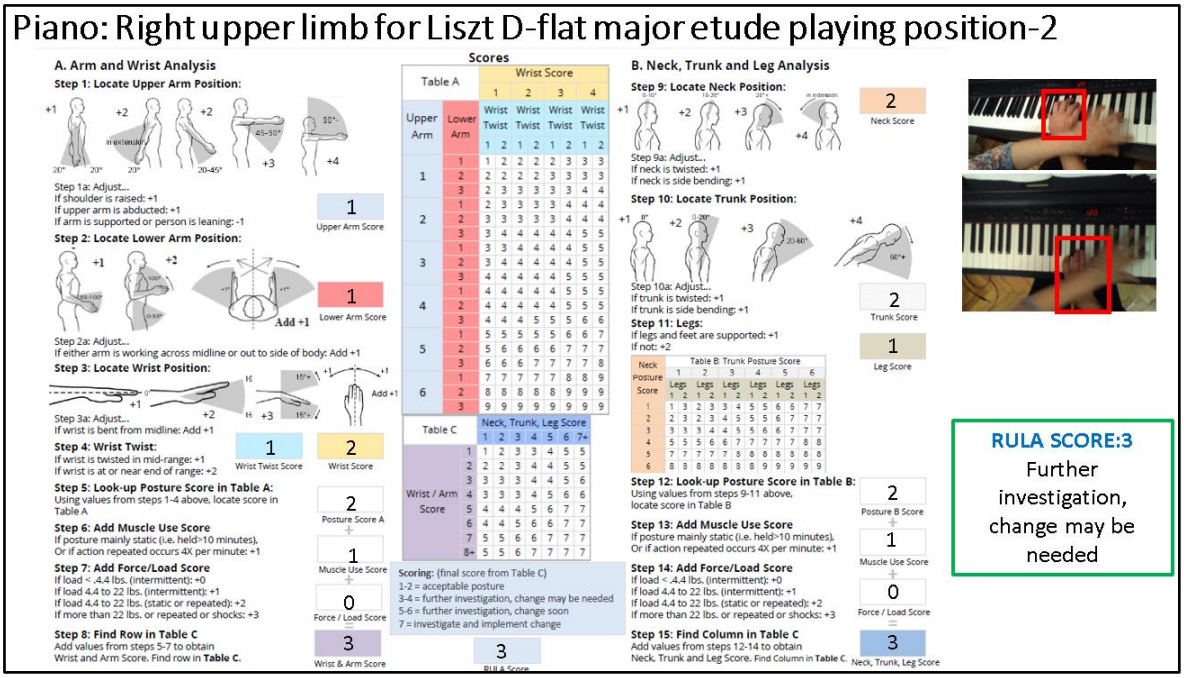


Figure C.18. RULA evaluation for piano: Right upper limb for Liszt D-flat major etude playing position-2

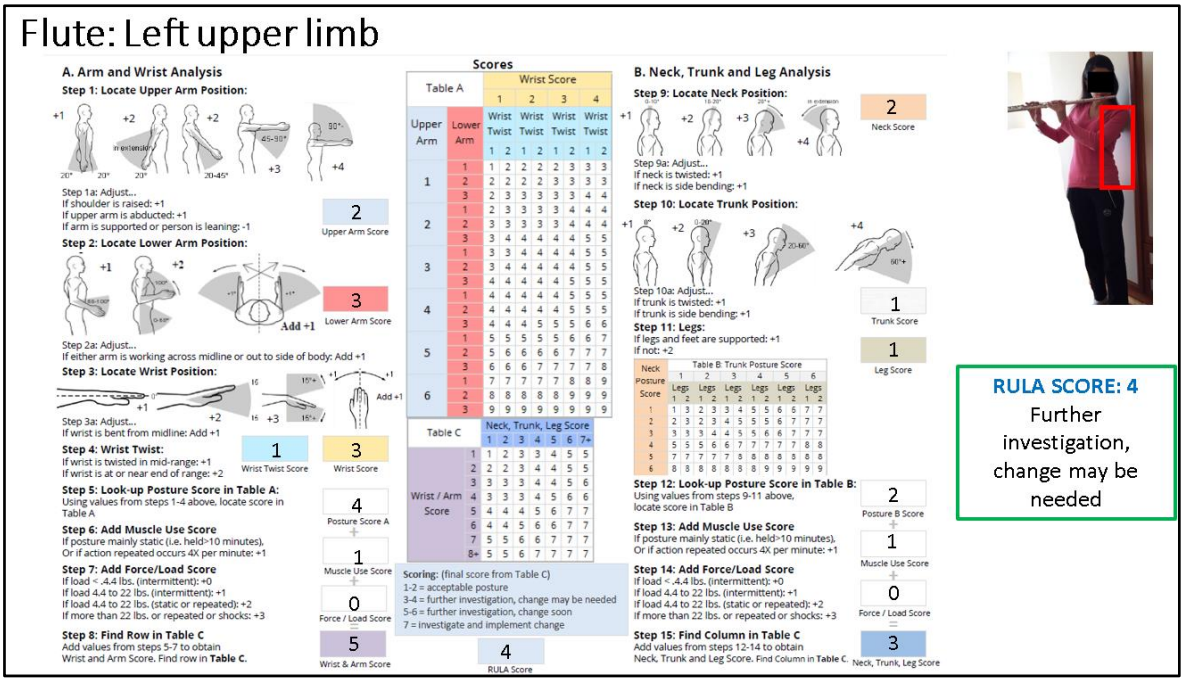


Figure C.19. RULA evaluation for flute: Left upper limb

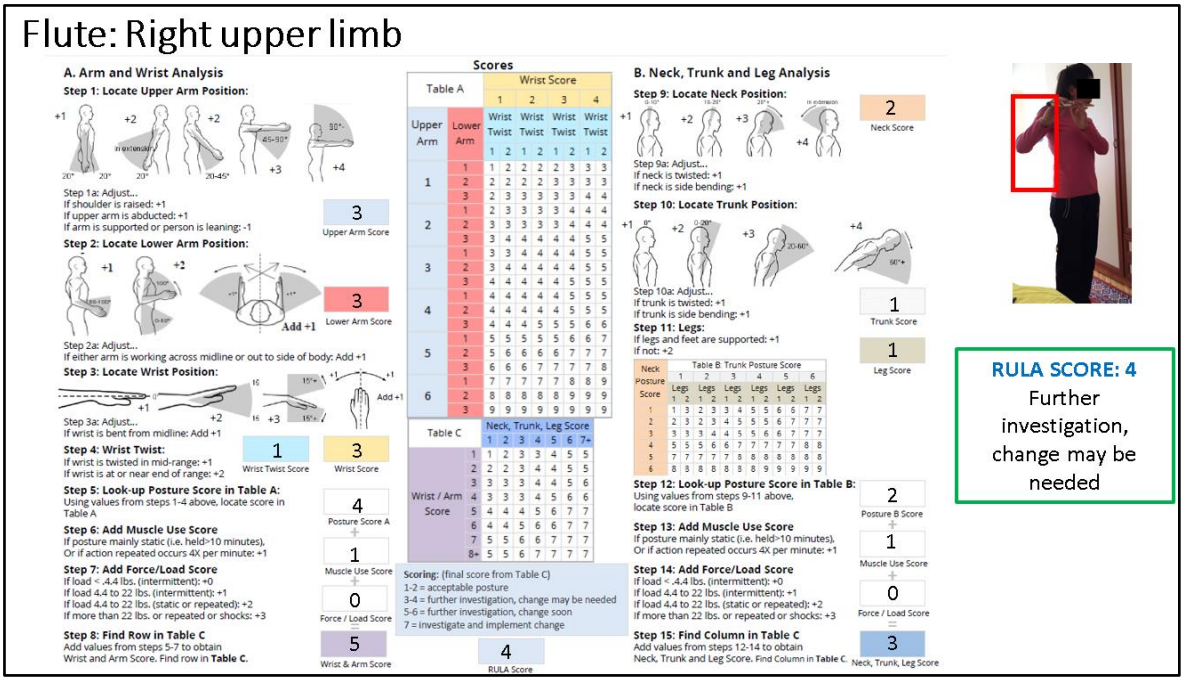


Figure C.20. RULA evaluation for flute: Right upper limb

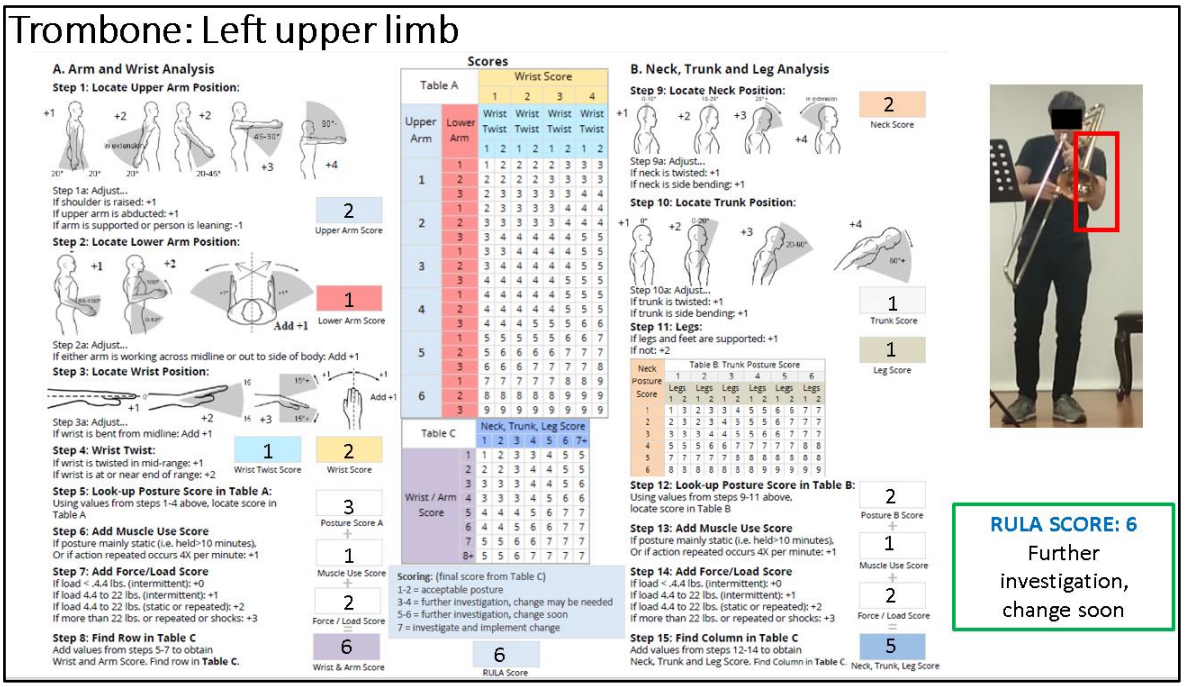


Figure C.21. RULA evaluation for trombone: Left upper limb

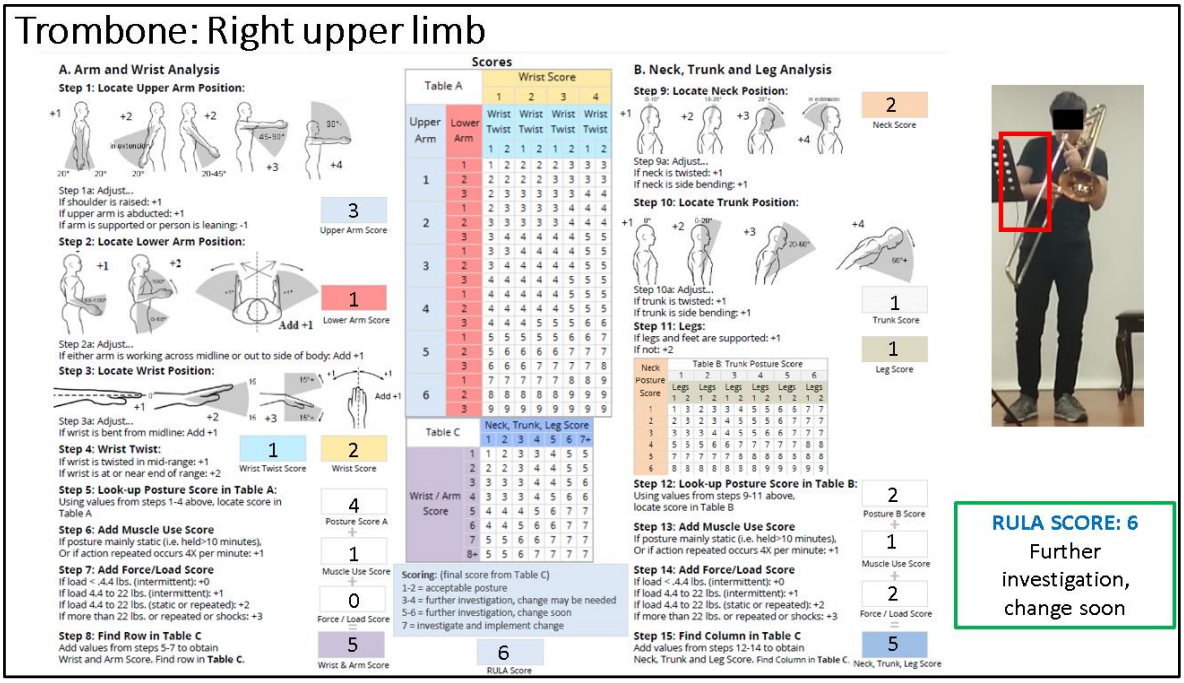


Figure C.22. RULA evaluation for trombone: Right upper limb

APPENDIX D: UNSTATISFIED ANOVA ASSUMPTIONS

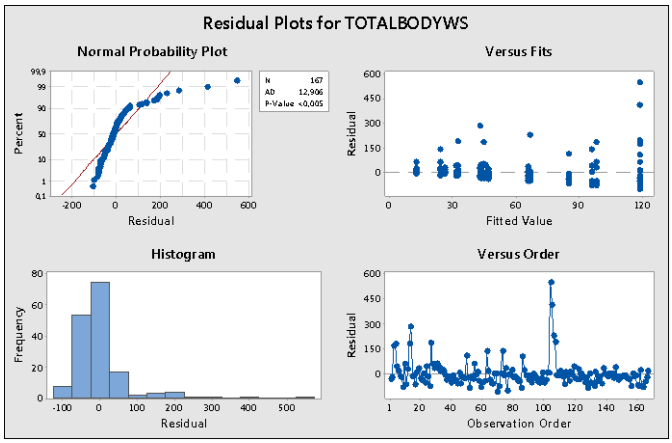


Figure D.1. The unsatisfied ANOVA assumptions of TBWS of females

Table D.1. The Levene's Test result of TBWS of females

Output	Levene's Test Result
TBWS of females	0.017

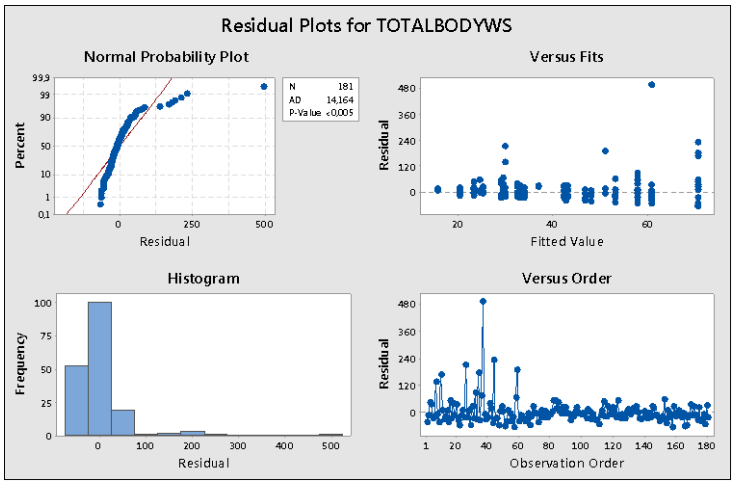


Figure D.2. The unsatisfied ANOVA assumptions of TBWS of males

Table D.2. The Levene's Test result of TBWS of males

Output	Levene's Test Result
TBWS of males	0.029

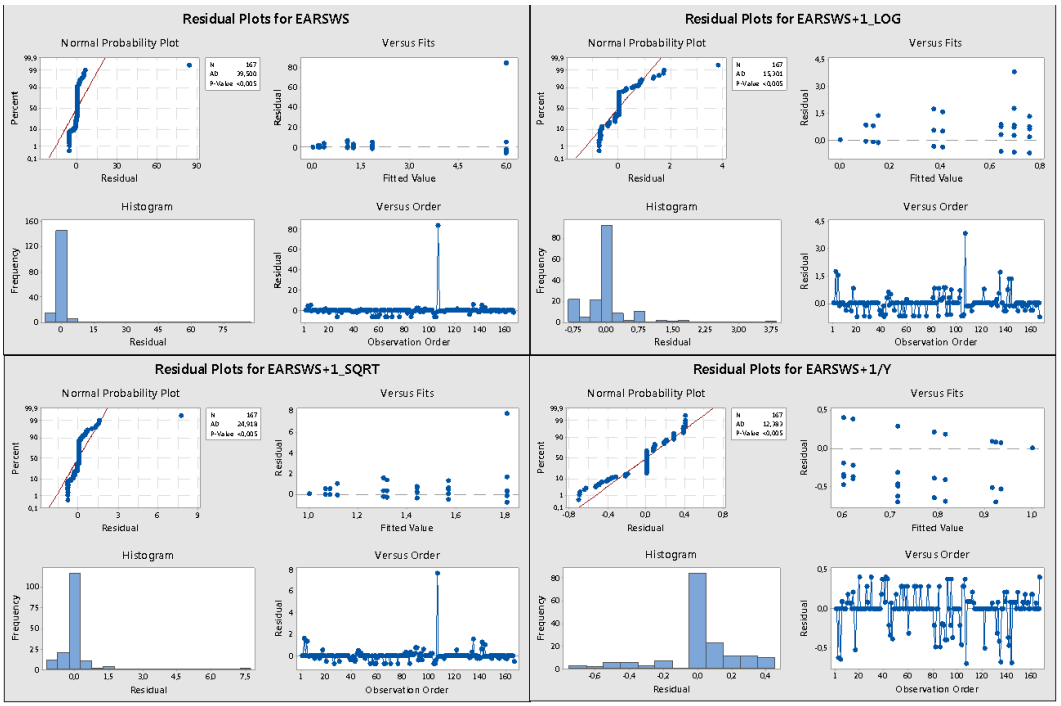


Figure D.3. The unsatisfied ANOVA assumptions of ears weighted scores of females

Table D.3. The Levene's Test results for ears weighted scores of females

Output	**Levene's Test Result**
Ears weighted scores of females	0.012
Ears weighted scores of females: log(Y) transformation	<0.001
Ears weighted scores of females: sqrt(Y) transformation	0.033
Ears weighted scores of females: 1/Y transformation	<0.001

Table D.4. The Levene's Test results for ears weighted scores of males

Output	**Levene's Test Result**
Ears weighted scores of males	0.810
Ears weighted scores of males: log(Y) transformation	0.500
Ears weighted scores of males: sqrt(Y) transformation	0.431
Ears weighted scores of males: 1/Y transformation	0.170

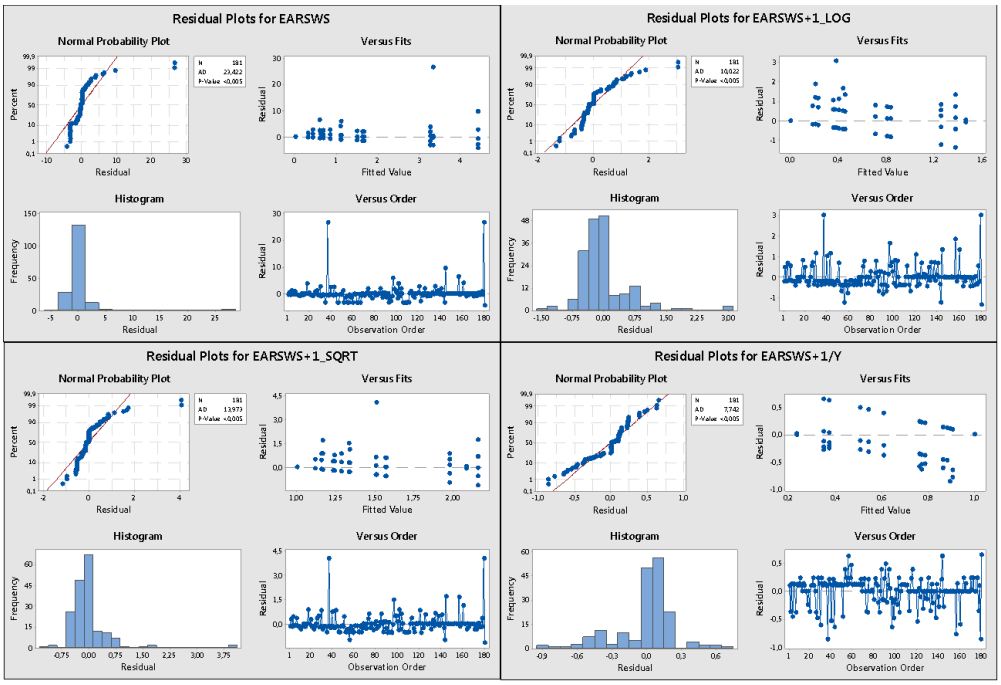


Figure D.4. The unsatisfied ANOVA assumptions of ears weighted scores of males

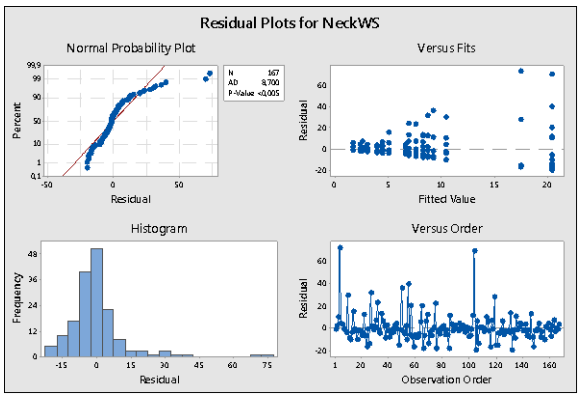


Figure D.5. The unsatisfied ANOVA assumptions of neck weighted scores of females

Table D.5. The Levene's Test result for neck weighted scores of females

Output	Levene's Test Result
Neck weighted scores of females	0.008

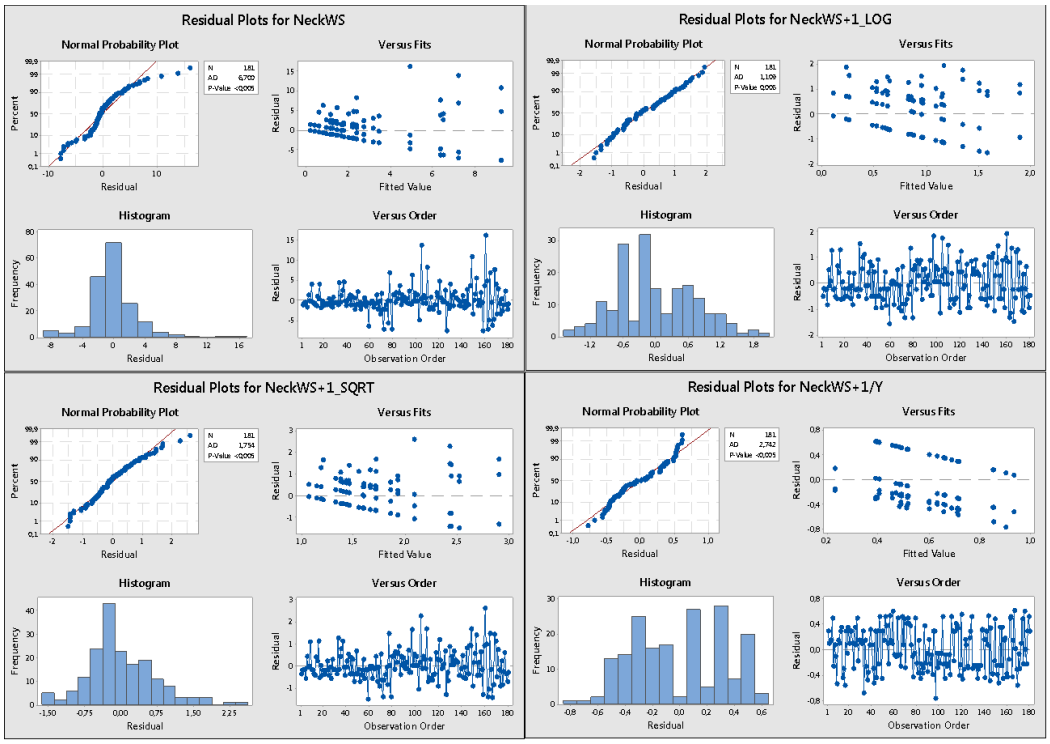


Figure D.6. The unsatisfied ANOVA assumptions of neck weighted scores of males

Table D.6. The Levene's Test results for neck weighted scores of males

Output	**Levene's Test Result**
Neck weighted scores of males	<0.001*
Neck weighted scores of males: log(Y) transformation	0.086
Neck weighted scores of males: sqrt(Y) transformation	<0.001*
Neck weighted scores of males: 1/Y transformation	0.754

Table D.7. The Levene's Test results for right shoulder weighted scores of females

Output	**Levene's Test Result**
Right shoulder weighted scores of females	0.377
Right shoulder weighted scores of females: log(Y) transformation	0.124
Right shoulder weighted scores of females: sqrt(Y) transformation	0.134
Right shoulder weighted scores of females: 1/Y transformation	0.830

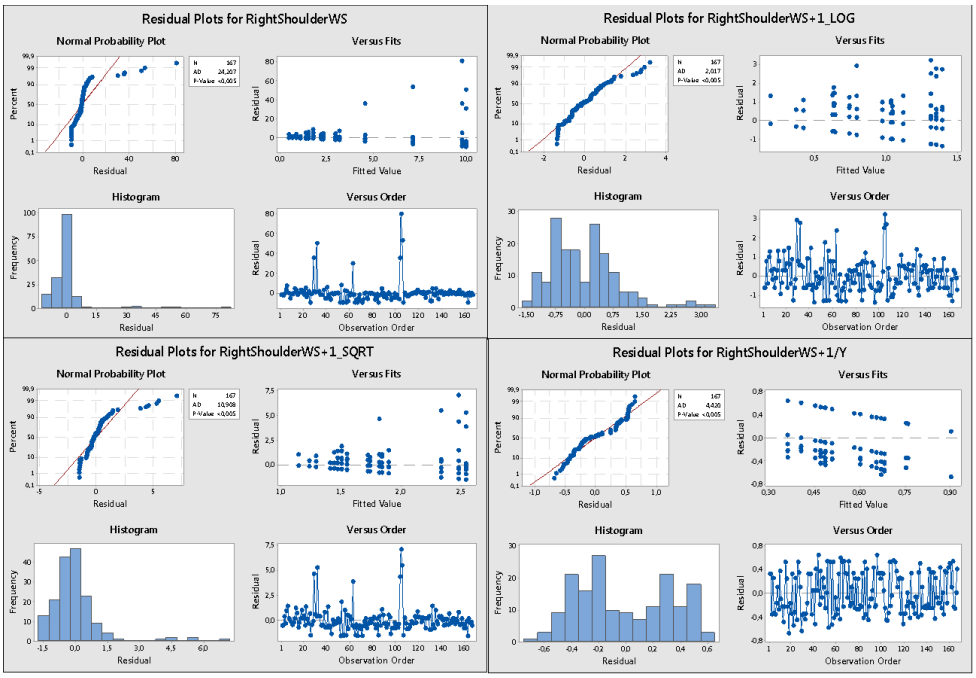


Figure D.7. The unsatisfied ANOVA assumptions of right shoulder weighted scores of females

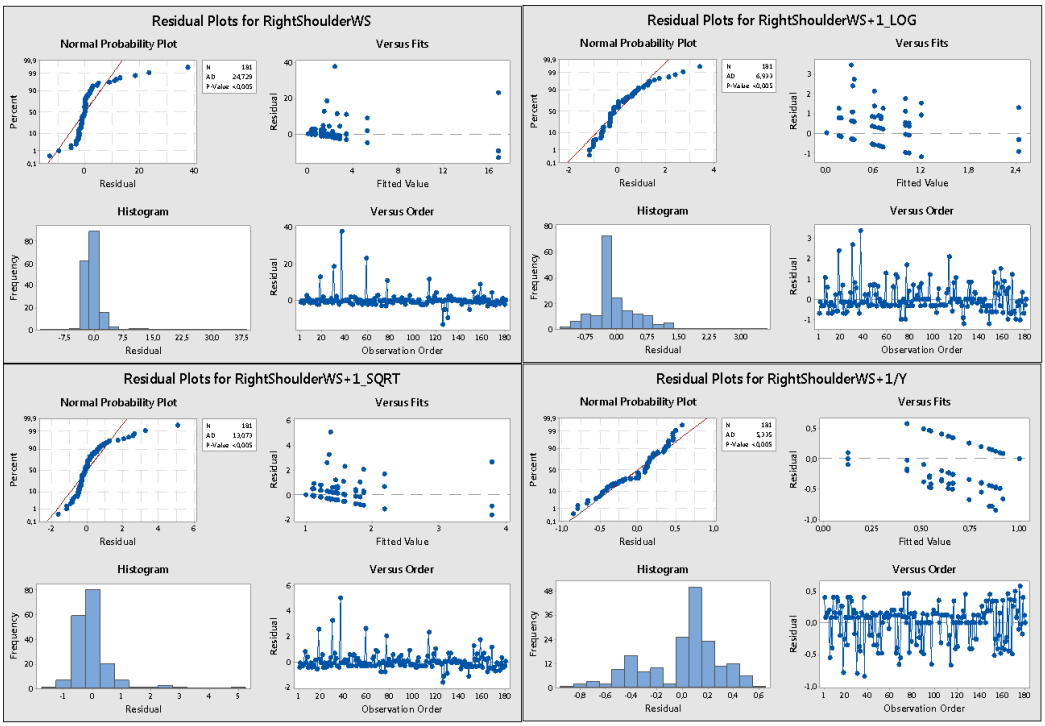


Figure D.8. The unsatisfied ANOVA assumptions of right shoulder weighted scores of males

Table D.8. The Levene's Test results for right shoulder weighted scores of males

Output	Levene's Test Result
Right shoulder weighted scores of males	0.248
Right shoulder weighted scores of males: log(Y) transformation	0.117
Right shoulder weighted scores of males: sqrt(Y) transformation	0.274
Right shoulder weighted scores of males: 1/Y transformation	0.025

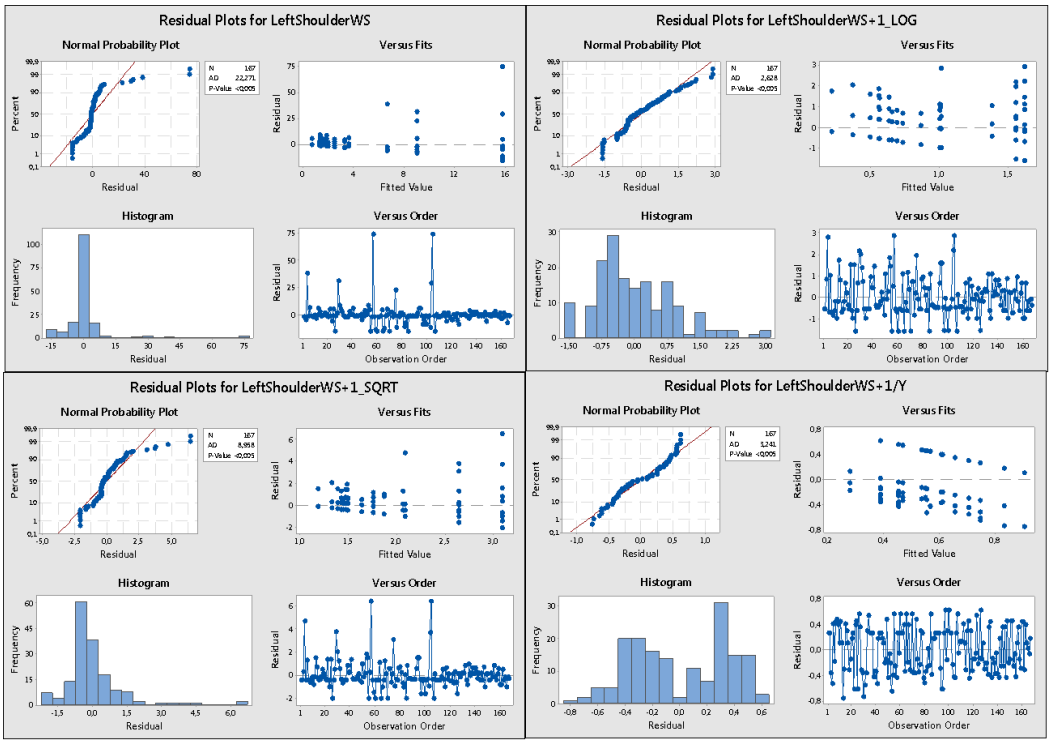


Figure D.9. The unsatisfied ANOVA assumptions of left shoulder weighted scores of females

Table D.9. The Levene's Test results for left shoulder weighted scores of females

Output	Levene's Test Result
Left shoulder weighted scores of females	0.014
Left shoulder weighted scores of females: log(Y) transformation	0.008
Left shoulder weighted scores of females: sqrt(Y) transformation	0.001
Left shoulder weighted scores of females: 1/Y transformation	0.649

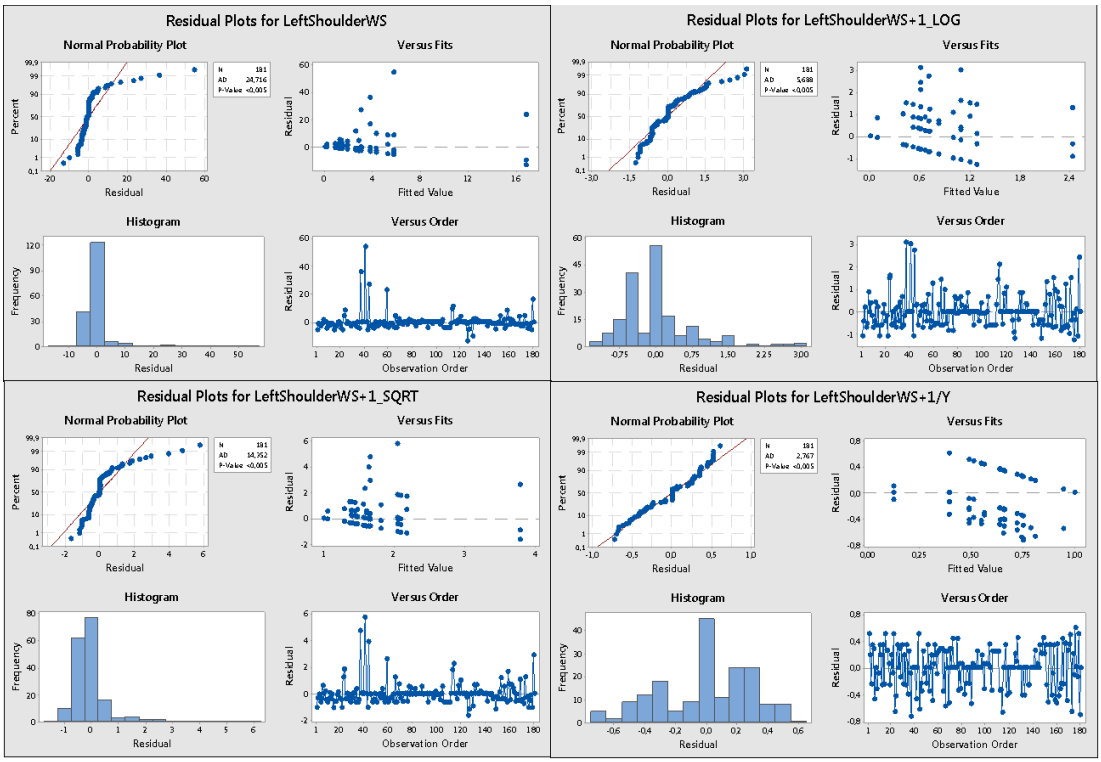


Figure D.10. The unsatisfied ANOVA assumptions of left shoulder weighted scores of males

Table D.10.The Levene's Test results for left shoulder weighted scores of males

Output	**Levene's Test Result**
Left shoulder weighted scores of males	0.674
Left shoulder weighted scores of males: log(Y) transformation	0.029
Left shoulder weighted scores of males: sqrt(Y) transformation	0.172
Left shoulder weighted scores of males: 1/Y transformation	<0.001

Table D.11. The Levene's Test results for upper back weighted scores of females

Output	**Levene's Test Result**
Upper back weighted scores of females	0.005
Upper back weighted scores of females: log(Y) transformation	<0.001
Upper back weighted scores of females: sqrt(Y) transformation	<0.001
Upper back weighted scores of females: 1/Y transformation	0.178

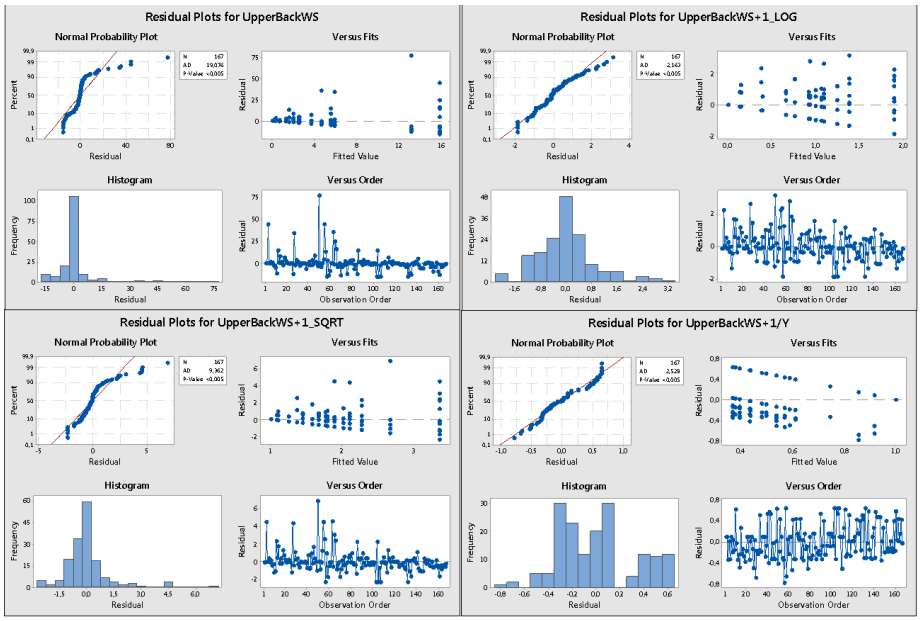


Figure D.11. The unsatisfied ANOVA assumptions of upper back weighted scores of females

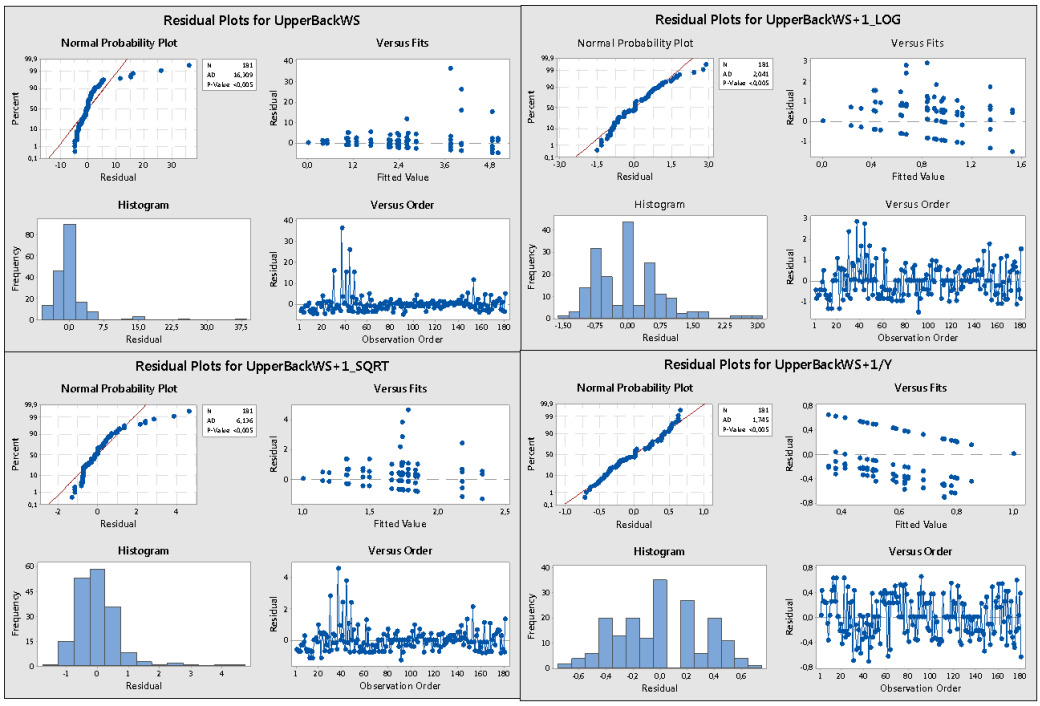


Figure D.12. The unsatisfied ANOVA assumptions of upper back weighted scores of males

Table D.12. The Levene's Test results for upper back weighted scores of males

Output	Levene's Test Result
Upper back weighted scores of males	0.501
Upper back weighted scores of males: log(Y) transformation	0.129
Upper back weighted scores of males: sqrt(Y) transformation	0.435
Upper back weighted scores of males: 1/Y transformation	0.086

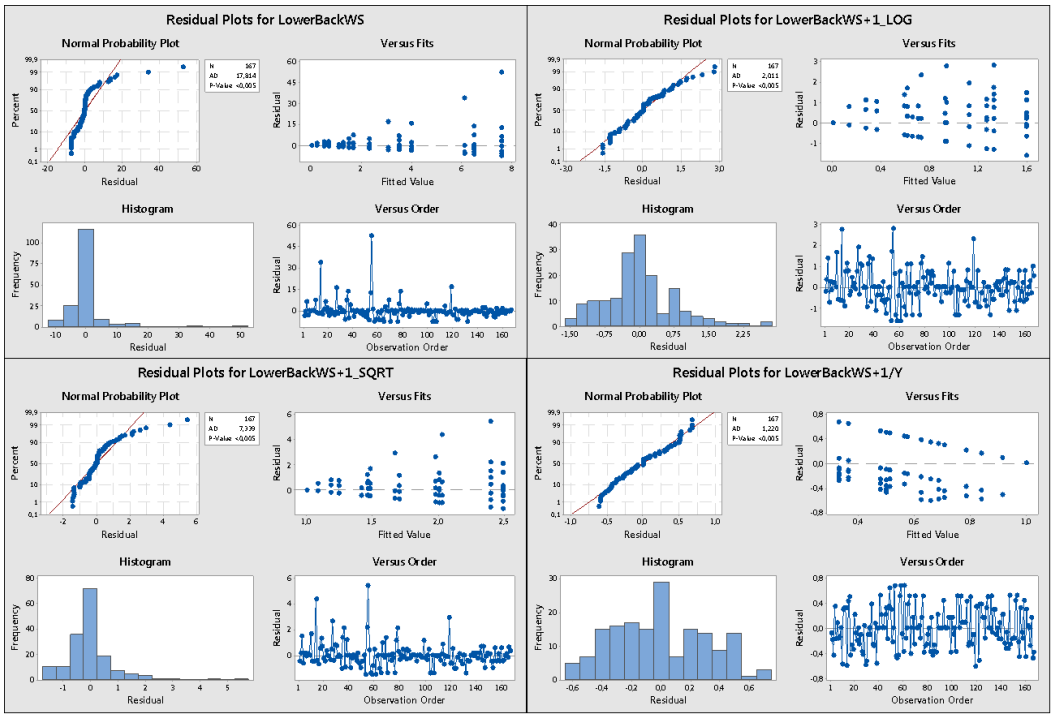


Figure D.13. The unsatisfied ANOVA assumptions of lower back weighted scores of females

Table D.13. The Levene's Test results for lower back weighted scores of females

Output	Levene's Test Result
Lower back weighted scores of females	0.032
Lower back weighted scores of females: log(Y) transformation	<0.001
Lower back weighted scores of females: sqrt(Y) transformation	<0.001
Lower back weighted scores of females: 1/Y transformation	0.002

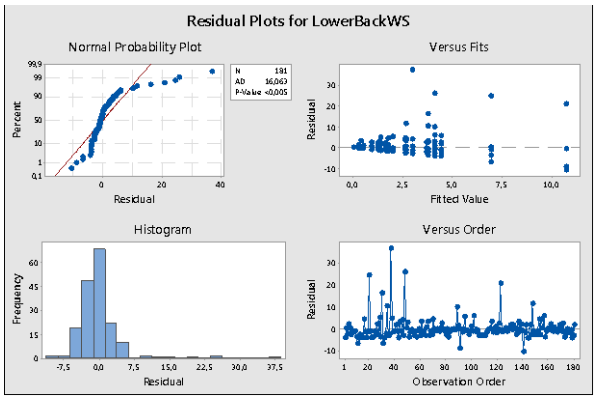


Figure D.14. The unsatisfied ANOVA assumptions of lower back weighted scores of males

Table D.14. The Levene's Test result for lower back weighted scores of males

Output	**Levene's Test Result**
Lower back weighted scores of males	<0.001

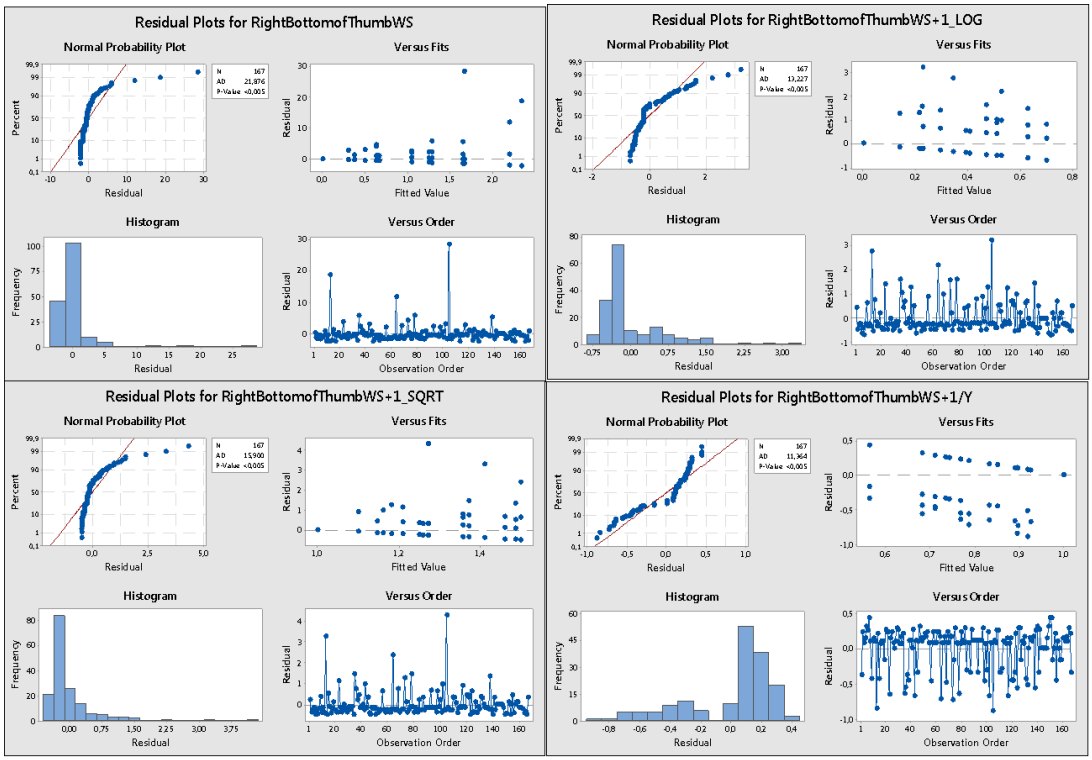


Figure D.15. The unsatisfied ANOVA assumptions of right bottom of thumb weighted scores of females

Table D.15. The Levene's Test results for right bottom of thumb weighted scores of females

Output	Levene's Test Result
Right bottom of thumb weighted scores of females	0.970
Right bottom of thumb weighted scores of females: log(Y) transformation	0.885
Right bottom of thumb weighted scores of females: sqrt(Y) transformation	0.942
Right bottom of thumb weighted scores of females: 1/Y transformation	0.526

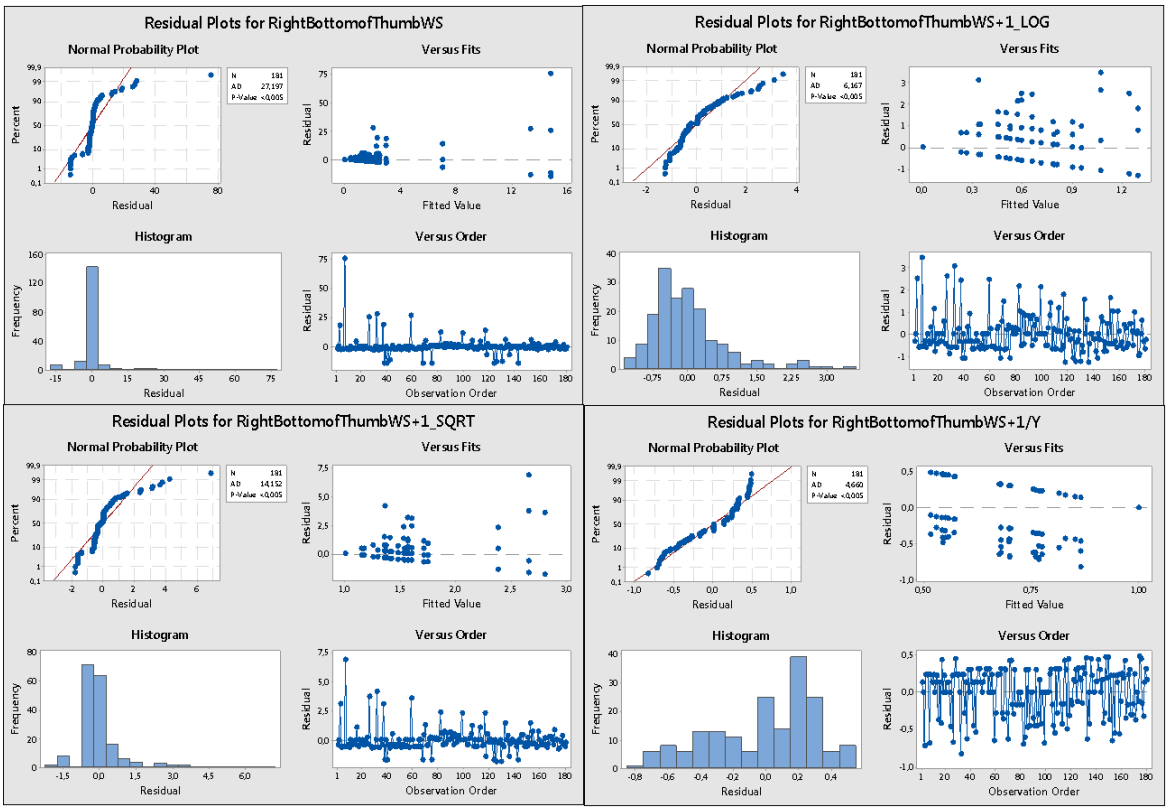


Figure D.16. The unsatisfied ANOVA assumptions of right bottom of thumb weighted scores of males

Table D.16. The Levene's Test results for right bottom of thumb weighted scores of males

Output	Levene's Test Result
Right bottom of thumb weighted scores of males	0.167
Right bottom of thumb weighted scores of males: log(Y) transformation	0.480
Right bottom of thumb weighted scores of males: sqrt(Y) transformation	0.281
Right bottom of thumb weighted scores of males: 1/Y transformation	0.597

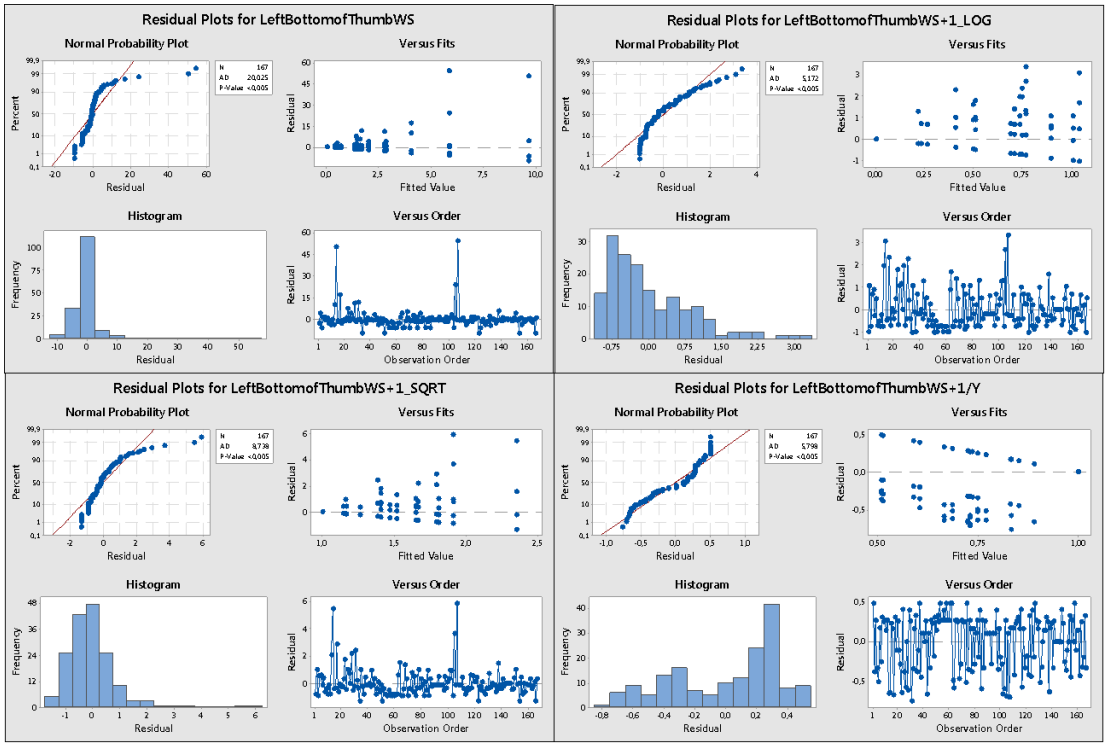


Figure D.17. The unsatisfied ANOVA assumptions of left bottom of thumb weighted scores of females

Table D.17. The Levene's Test results for left bottom of thumb weighted scores of females

Output	Levene's Test Result
Left bottom of thumb weighted scores of females	0.304
Left bottom of thumb weighted scores of females: log(Y) transformation	0.428
Left bottom of thumb weighted scores of females: sqrt(Y) transformation	0.306
Left bottom of thumb weighted scores of females: 1/Y transformation	0.712

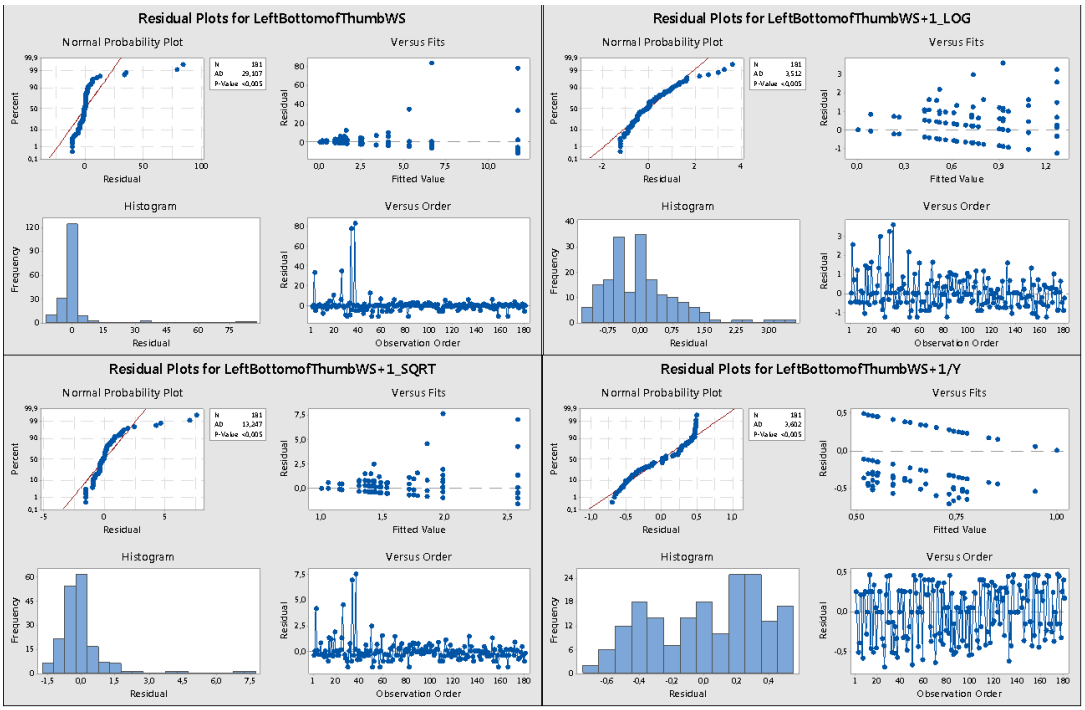


Figure D.18. The unsatisfied ANOVA assumptions of left bottom of thumb weighted scores of males

Table D.18. The Levene's Test results for left bottom of thumb weighted scores of males

Output	**Levene's Test Result**
Left bottom of thumb weighted scores of males	0.794
Left bottom of thumb weighted scores of males: log(Y) transformation	0.048
Left bottom of thumb weighted scores of males: sqrt(Y) transformation	0.317
Left bottom of thumb weighted scores of males: 1/Y transformation	0.137

Table D.19. The Levene's Test results for right thumb weighted scores of females

Output	**Levene's Test Result**
Right thumb weighted scores of females	0.208
Right thumb weighted scores of females: log(Y) transformation	0.002
Right thumb weighted scores of females: sqrt(Y) transformation	0.009
Right thumb weighted scores of females: 1/Y transformation	0.334

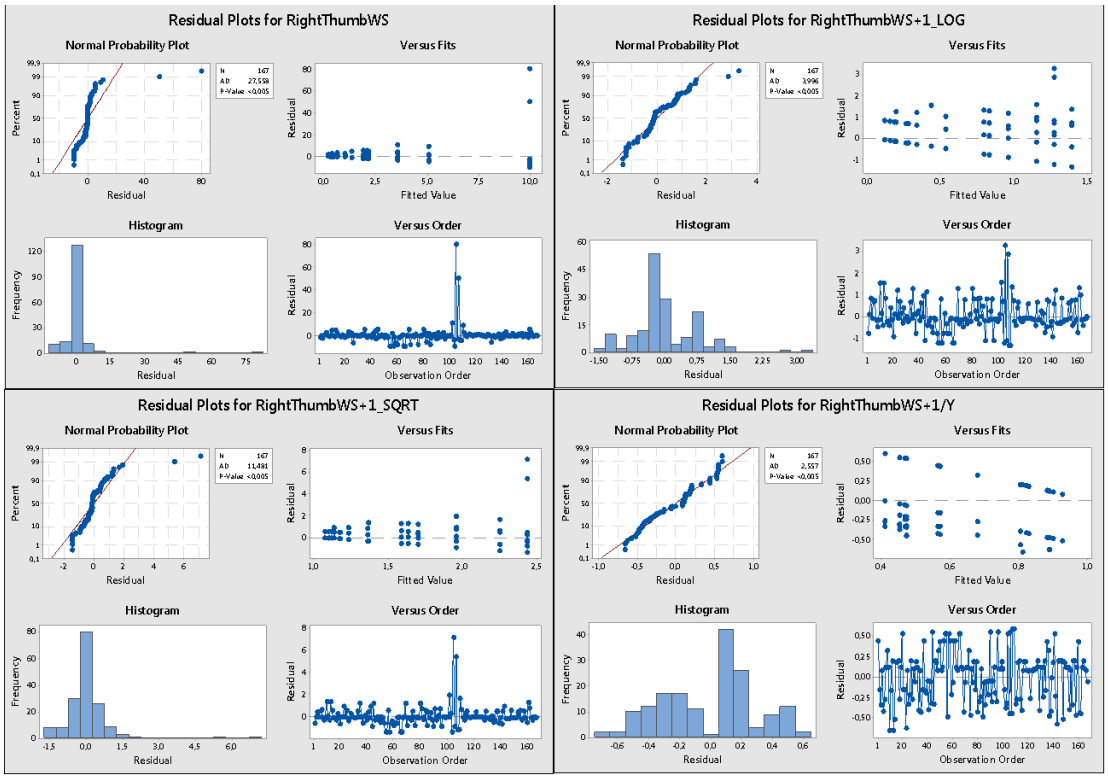


Figure D.19. The unsatisfied ANOVA assumptions of right thumb weighted scores of females

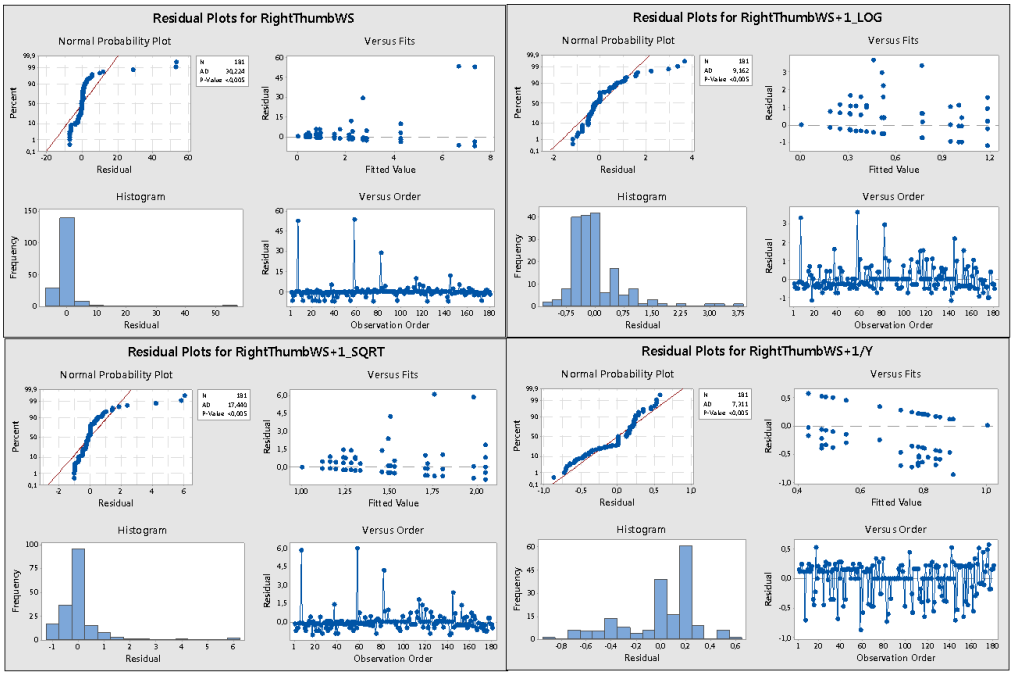


Figure D.20. The unsatisfied ANOVA assumptions of right thumb weighted scores of males

Table D.20. The Levene's Test results for right thumb weighted scores of males

Output	Levene's Test Result
Right thumb weighted scores of males	0.872
Right thumb weighted scores of males: log(Y) transformation	0.686
Right thumb weighted scores of males: sqrt(Y) transformation	0.778
Right thumb weighted scores of males: 1/Y transformation	0.495

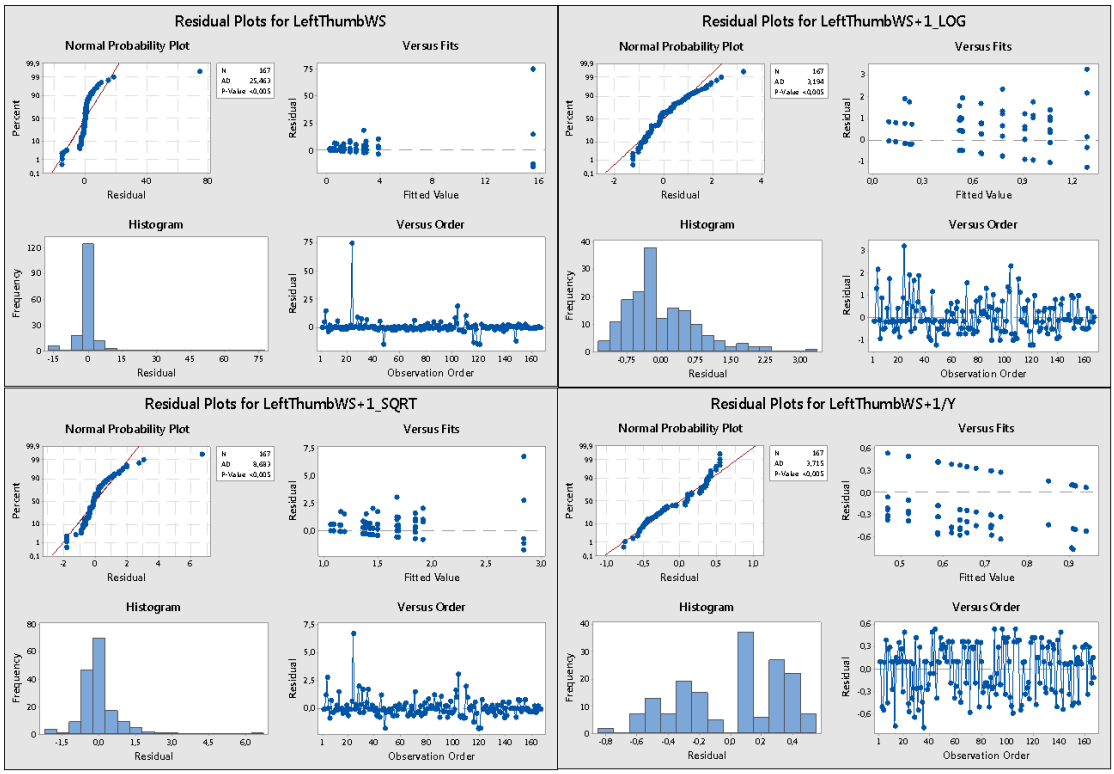


Figure D.21. The unsatisfied ANOVA assumptions of left thumb weighted scores of females

Table D.21.The Levene's Test results for left thumb weighted scores of females

Output	Levene's Test Result
Left thumb weighted scores of females	0.011
Left thumb weighted scores of females: log(Y) transformation	0.023
Left thumb weighted scores of females: sqrt(Y) transformation	0.009
Left thumb weighted scores of females: 1/Y transformation	0.110

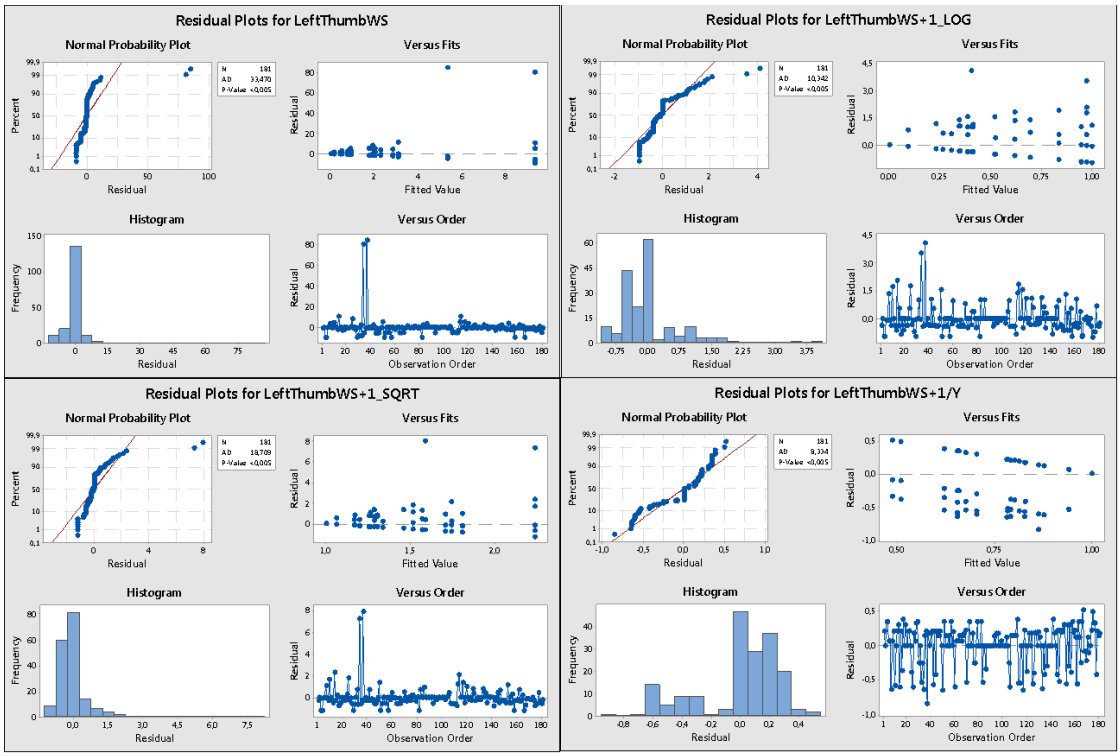


Figure D.22. The unsatisfied ANOVA assumptions of left thumb weighted scores of males

Table D.22. The Levene's Test results for left thumb weighted scores of males

Output	**Levene's Test Result**
Left thumb weighted scores of males	0.947
Left thumb weighted scores of males: log(Y) transformation	0.263
Left thumb weighted scores of males: sqrt(Y) transformation	0.558
Left thumb weighted scores of males: 1/Y transformation	0.073

Table D.23. The Levene's Test results for right wrist weighted scores of females

Output	**Levene's Test Result**
Right wrist weighted scores of females	0.637
Right wrist weighted scores of females: log(Y) transformation	0.016
Right wrist weighted scores of females: sqrt(Y) transformation	0.204
Right wrist weighted scores of females: 1/Y transformation	0.001

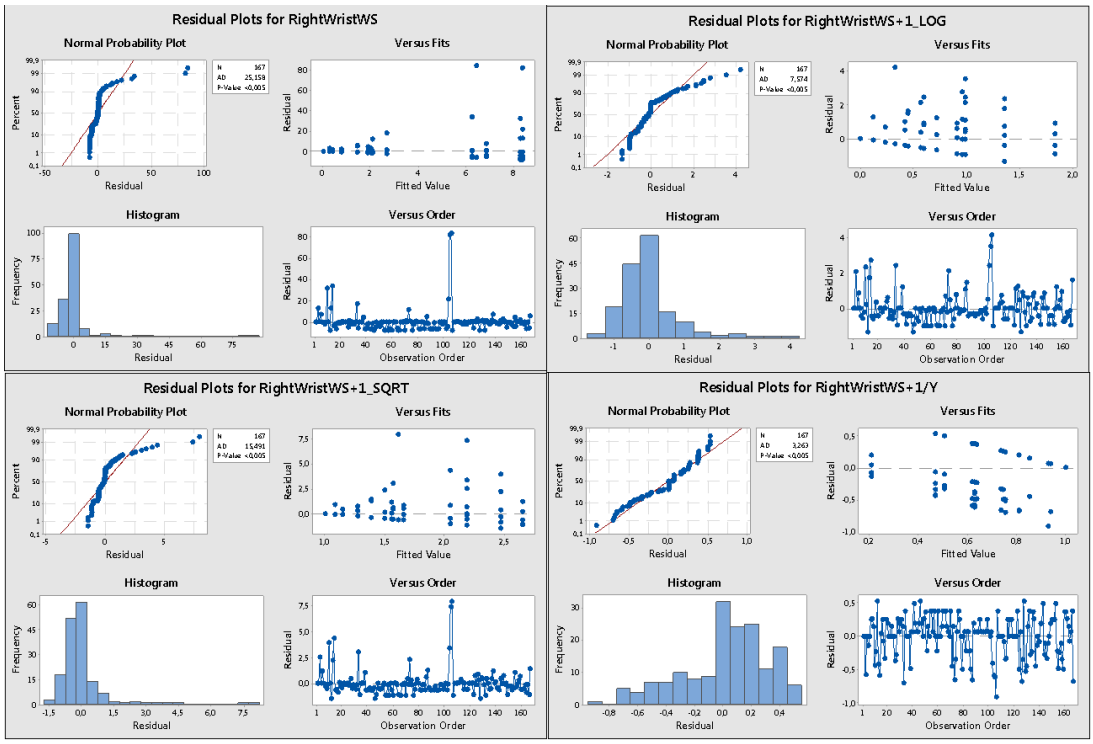


Figure D.23. The unsatisfied ANOVA assumptions of right wrist weighted scores of females

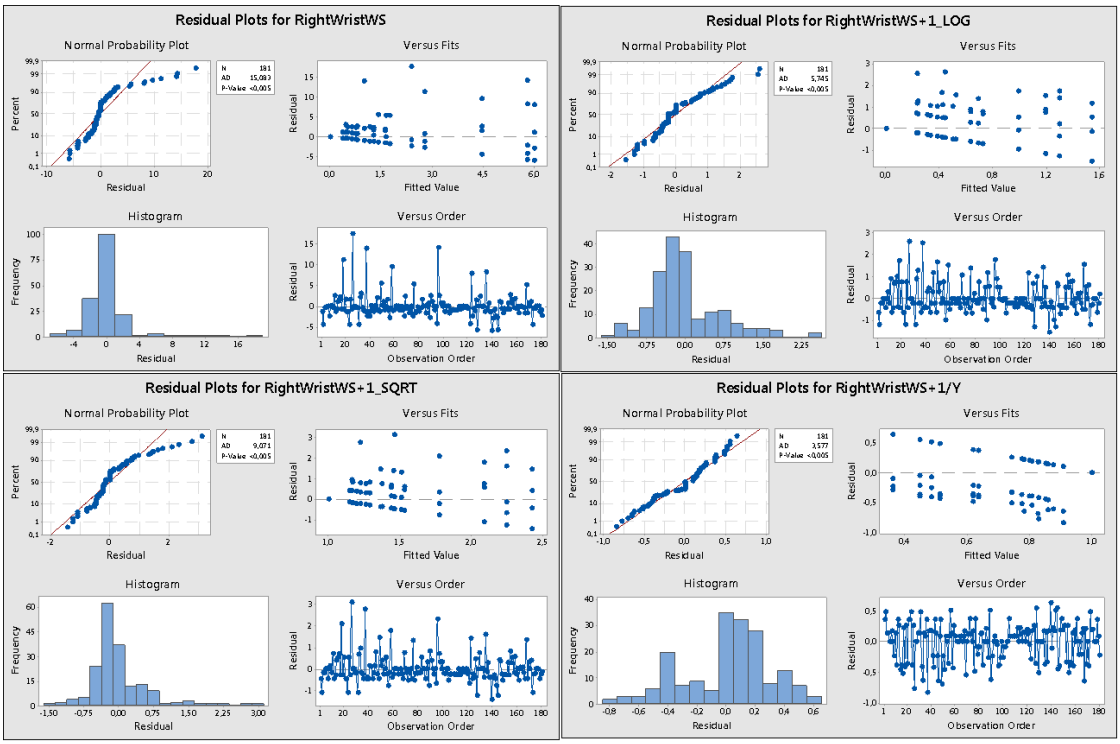


Figure D.24. The unsatisfied ANOVA assumptions of right wrist weighted scores of males

Table D.24. The Levene's Test results for right wrist weighted scores of males

Output	Levene's Test Result
Right wrist weighted scores of males	0.052
Right wrist weighted scores of males: log(Y) transformation	0.045
Right wrist weighted scores of males: sqrt(Y) transformation	0.024
Right wrist weighted scores of males: 1/Y transformation	0.085

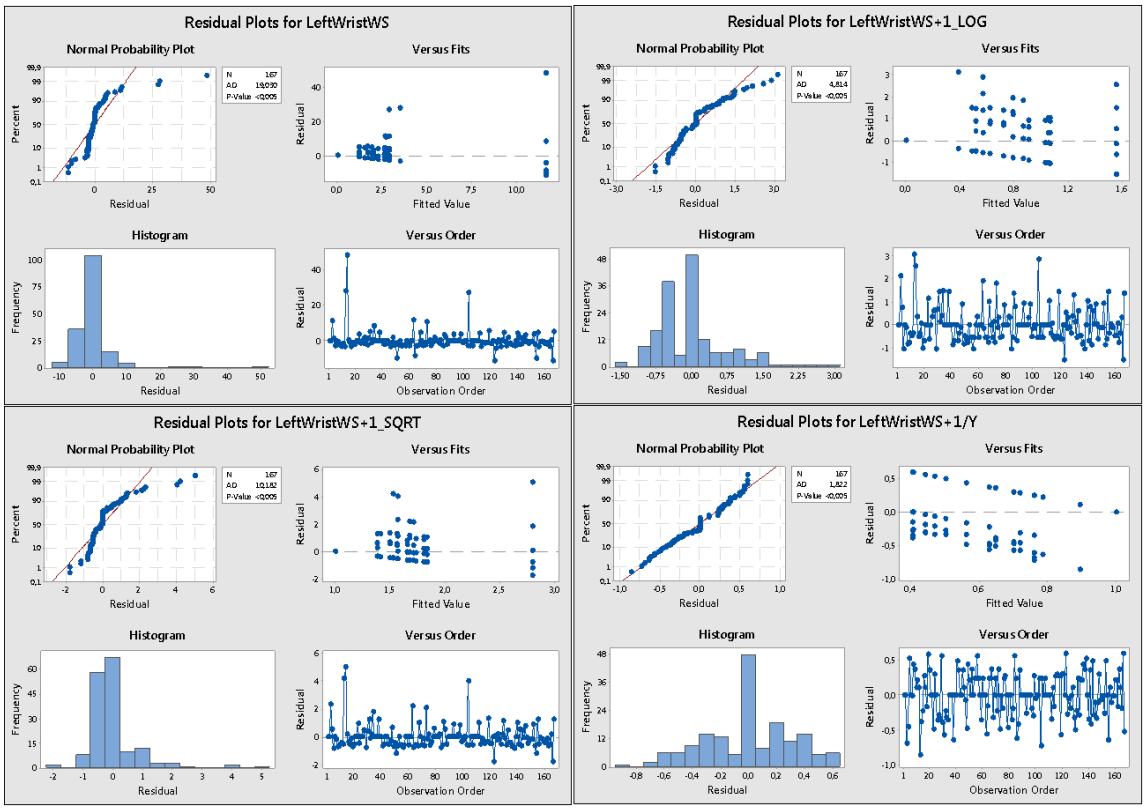


Figure D.25. The unsatisfied ANOVA assumptions of left wrist weighted scores of females

Table D.25. The Levene's Test results for left wrist weighted scores of females

Output	Levene's Test Result
Left wrist weighted scores of females	0.069
Left wrist weighted scores of females: log(Y) transformation	0.021
Left wrist weighted scores of females: sqrt(Y) transformation	0.035
Left wrist weighted scores of females: 1/Y transformation	0.009

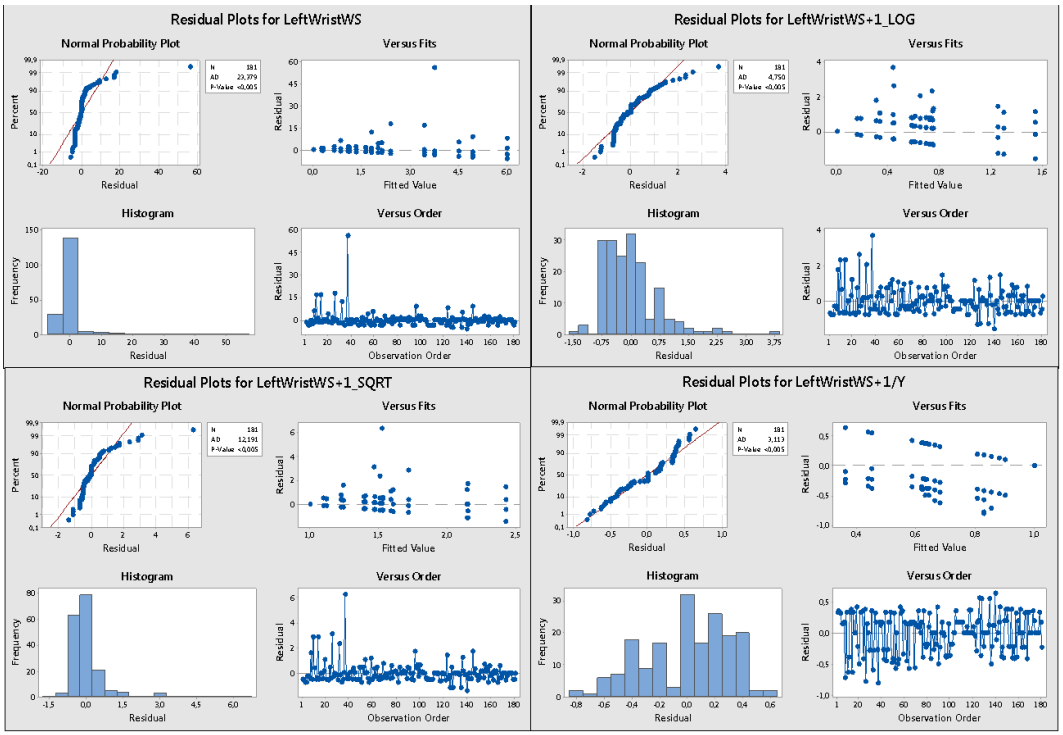


Figure D.26. The unsatisfied ANOVA assumptions of left wrist weighted scores of males

Table D.26. The Levene's Test results for left wrist weighted scores of males

Output	**Levene's Test Result**
Left wrist weighted scores of males	0.974
Left wrist weighted scores of males: log(Y) transformation	0.309
Left wrist weighted scores of males: sqrt(Y) transformation	0.714
Left wrist weighted scores of males: 1/Y transformation	0.145

Table D.27. The Levene's Test results for right wrist weighted scores of females

Output	**Levene's Test Result**
Right wrist weighted scores of females	0.637
Right wrist weighted scores of females: log(Y) transformation	0.016
Right wrist weighted scores of females: sqrt(Y) transformation	0.204
Right wrist weighted scores of females: 1/Y transformation	0.001

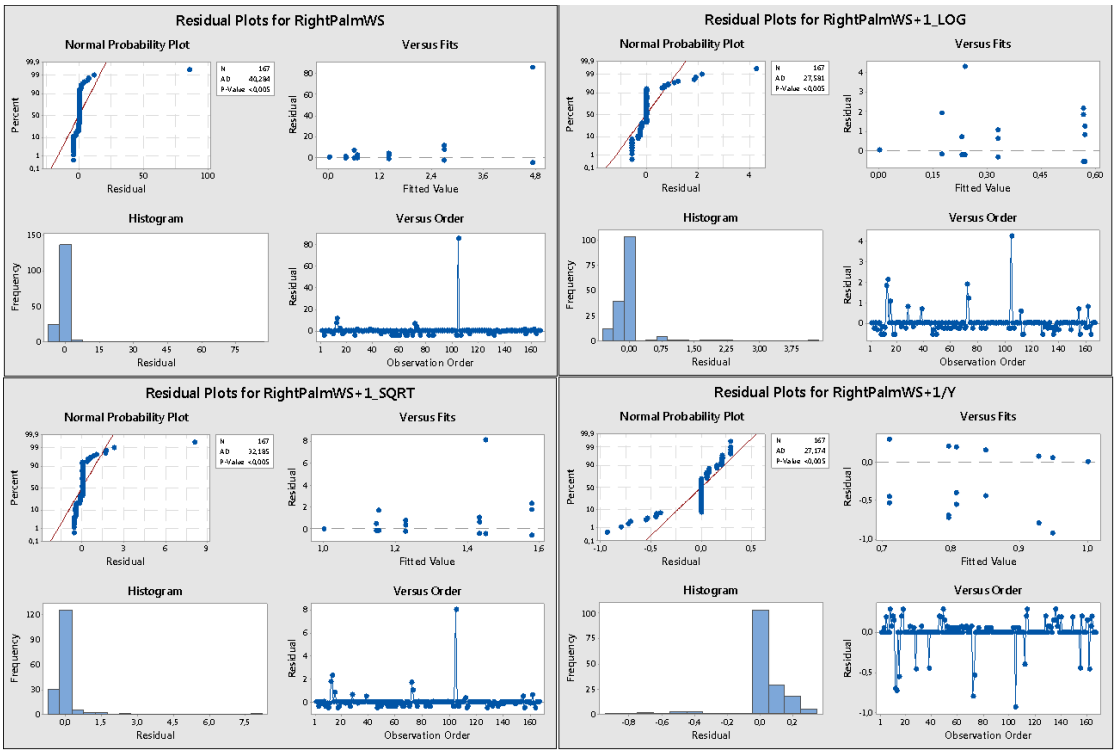


Figure D.27. The unsatisfied ANOVA assumptions of right palm weighted scores of females

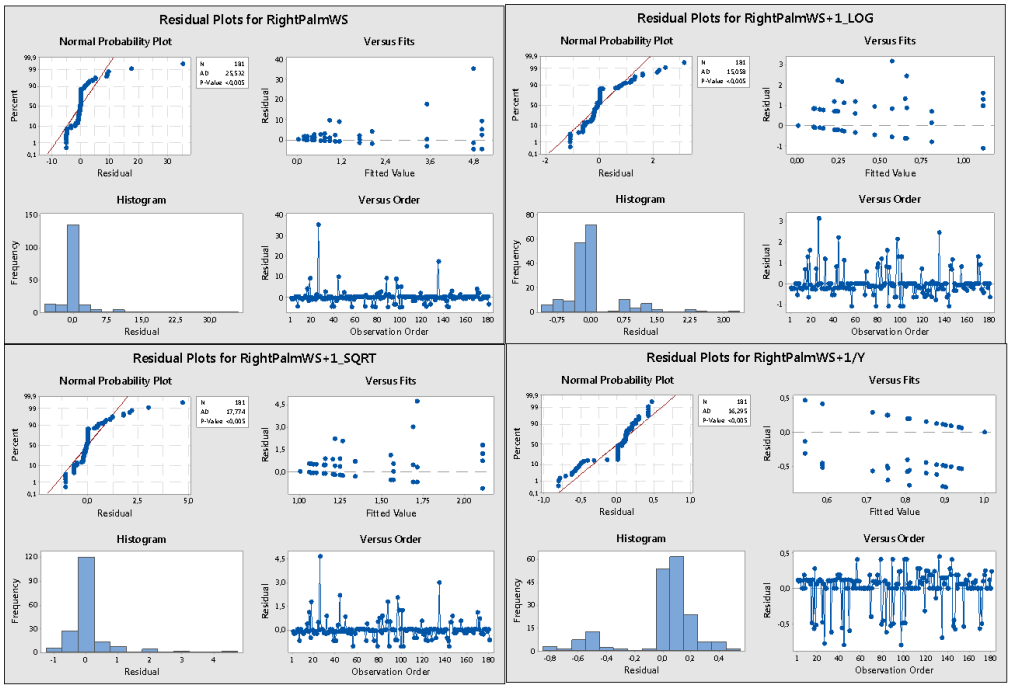


Figure D.28. The unsatisfied ANOVA assumptions of right palm weighted scores of males

Table D.28. The Levene's Test results for right palm weighted scores of males

Output	Levene's Test Result
Right palm weighted scores of males	0.226
Right palm weighted scores of males: log(Y) transformation	0.053
Right palm weighted scores of males: sqrt(Y) transformation	0.037
Right palm weighted scores of males: 1/Y transformation	0.035

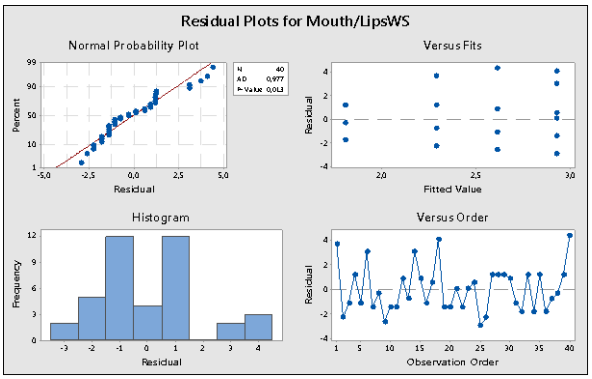


Figure D.29. The unsatisfied ANOVA assumptions of mouth/lips weighted scores of females

Table D.29. The Levene's Test result for mouth/lips weighted scores of females

Output	Levene's Test Result
Mouth/lips weighted scores of females	0.245

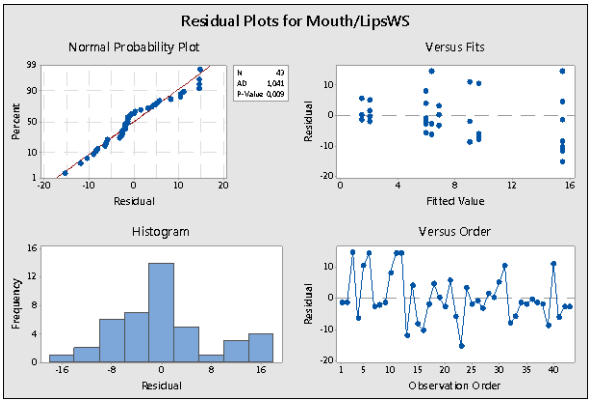


Figure D.30.The unsatisfied ANOVA assumptions of mouth/lips weighted scores of males

Table D.30. The Levene's Test result for mouth/lips weighted scores of males

Output	Levene's Test Result
Mouth/lips weighted scores of males	0.044

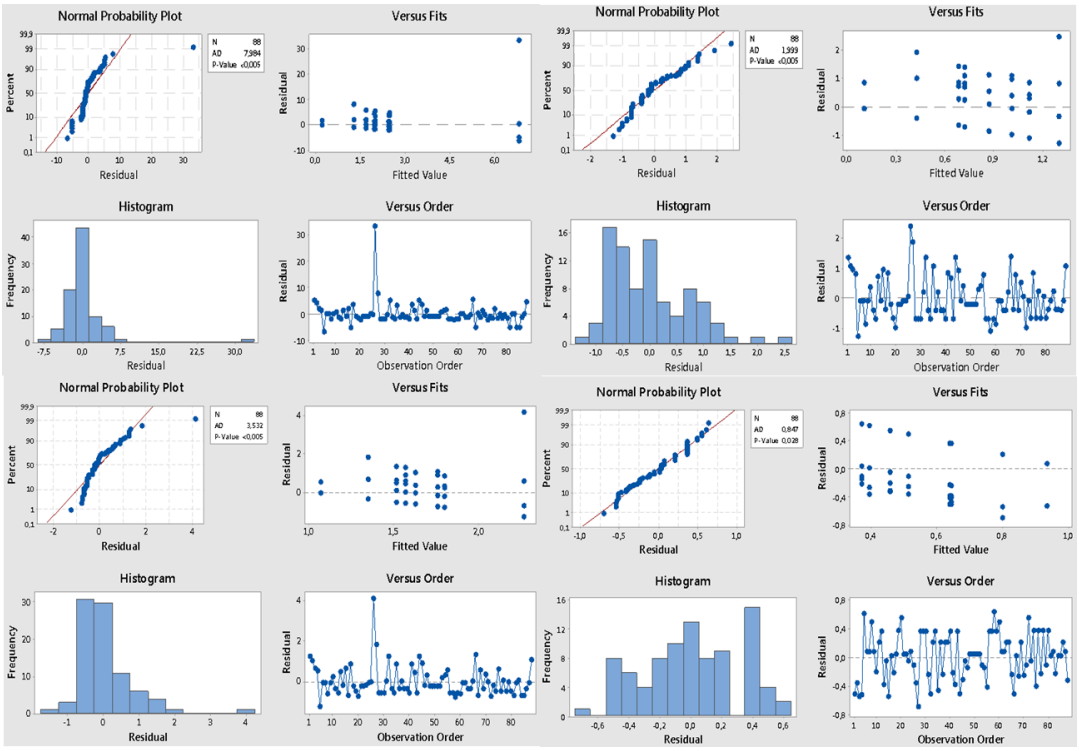


Figure D.31. The unsatisfied ANOVA assumptions of face/jaws weighted scores of females

Table D.31. The Levene's Test results for face/jaws weighted scores of females

Output	Levene's Test Result
Face/jaws weighted scores of females	0.348
Face/jaws weighted scores of females: log(Y) transformation	0.399
Face/jaws weighted scores of females: sqrt(Y) transformation	0.503
Face/jaws weighted scores of females: 1/Y transformation	0.118

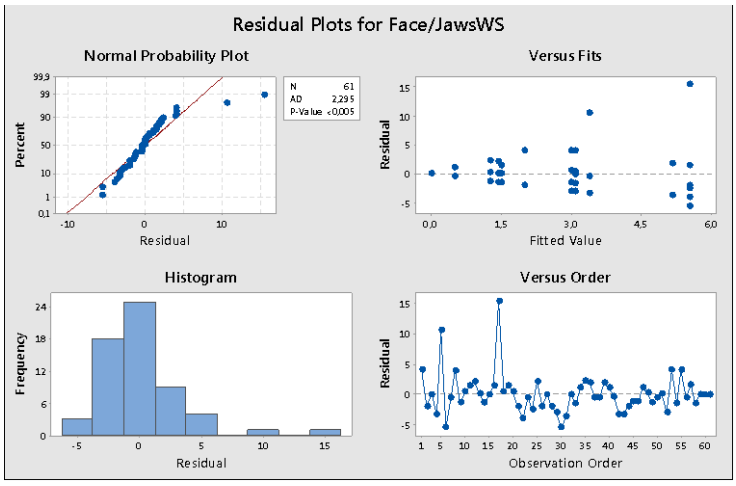


Figure D.32. The unsatisfied ANOVA assumptions of face/jaws weighted scores of males

Table D.32. The Levene's Test result for face/jaws weighted scores of males

Output	**Levene's Test Result**
Face/jaws weighted scores of females	0.485

Table D.33. The Levene's Test results for teeth weighted scores of females

Output	**Levene's Test Result**
Teeth weighted scores of females	0.593
Teeth weighted scores of females: log(Y) transformation	0.578
Teeth weighted scores of females: sqrt(Y) transformation	0.476
Teeth weighted scores of females: 1/Y transformation	0.390

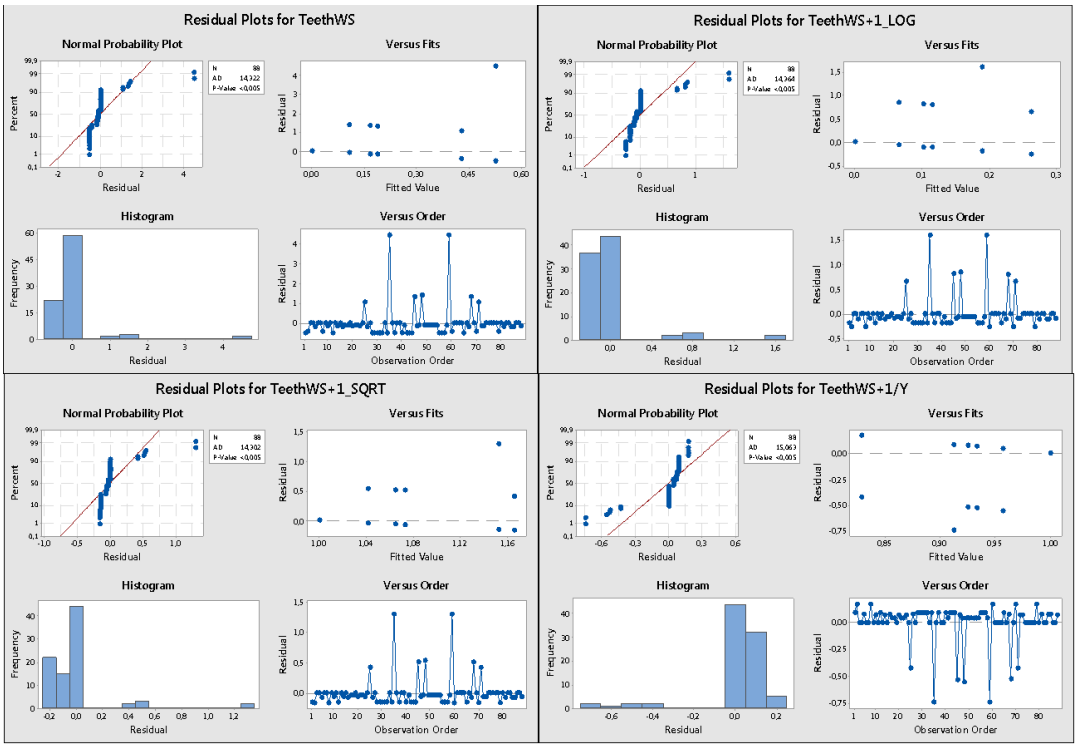


Figure D.33. The unsatisfied ANOVA assumptions of teeth weighted scores of females

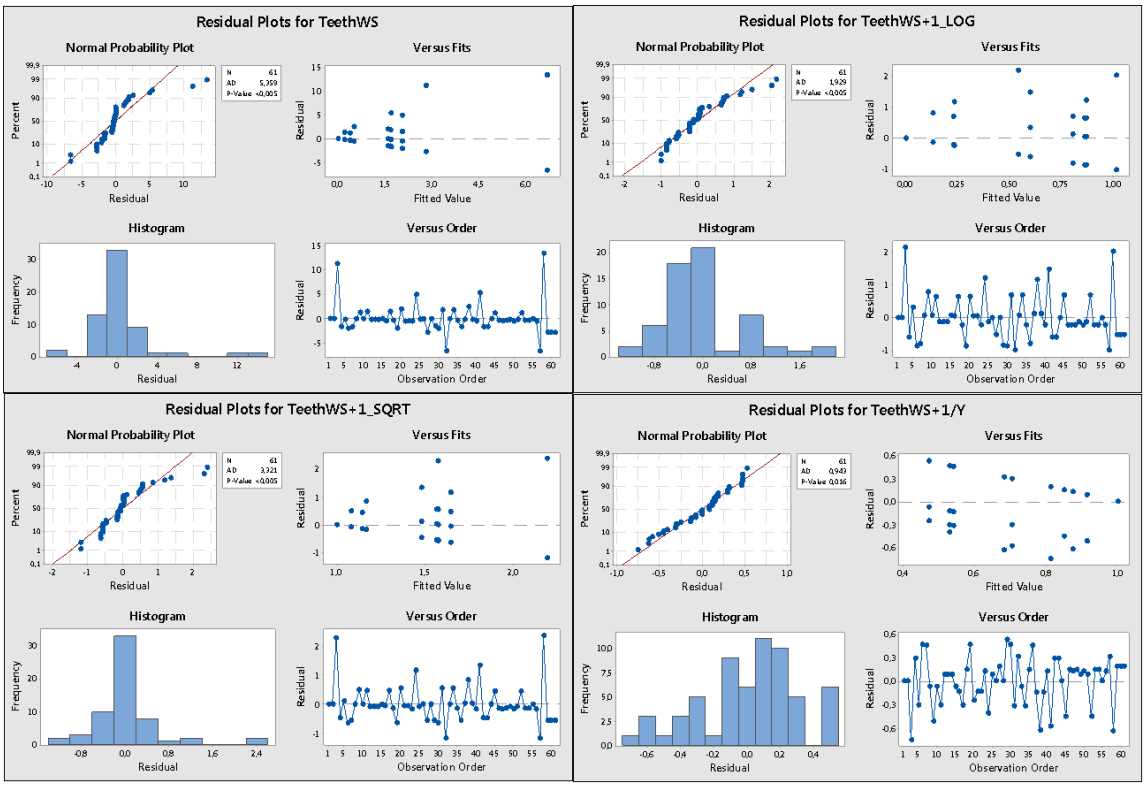


Figure D.34. The unsatisfied ANOVA assumptions of teeth weighted scores of males

Table D.34. The Levene's Test results for teeth weighted scores of males

Output	Levene's Test Result
Teeth weighted scores of males	0.342
Teeth weighted scores of males: log(Y) transformation	0.700
Teeth weighted scores of males: sqrt(Y) transformation	0.532
Teeth weighted scores of males: 1/Y transformation	0.81

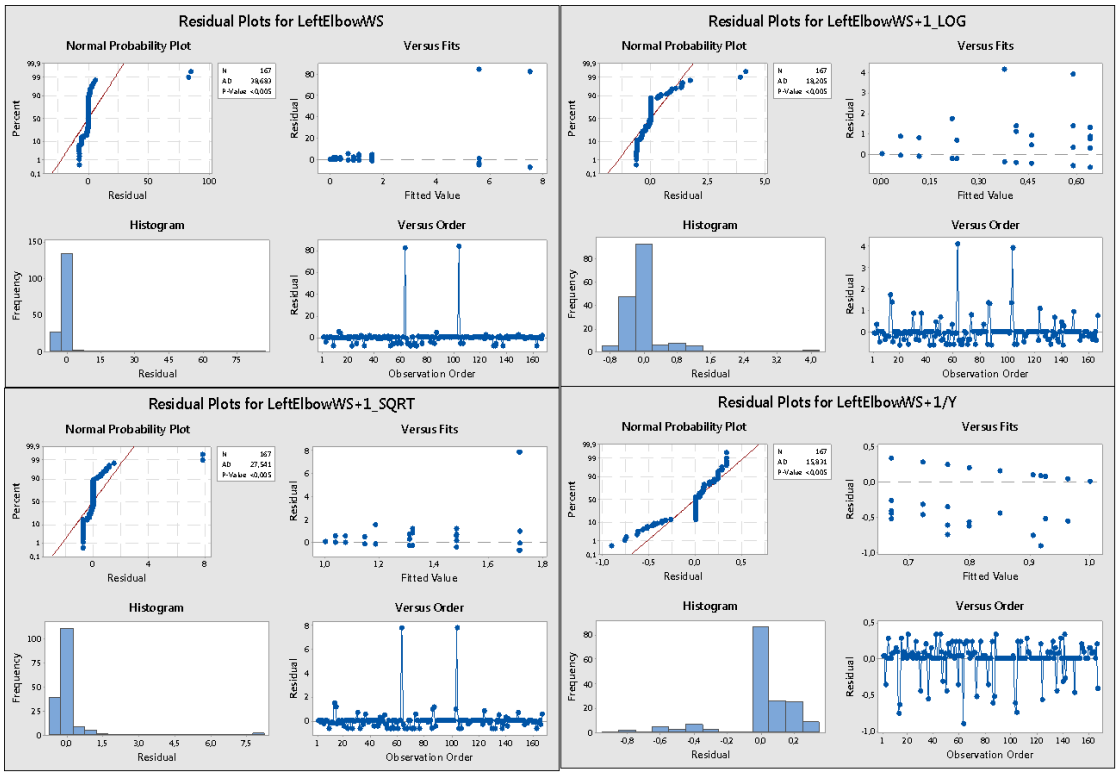


Figure D.35. The unsatisfied ANOVA assumptions of left elbow weighted scores of females

Table D.35. The Levene's Test results for left elbow weighted scores of females

Output	Levene's Test Result
Left elbow weighted scores of females	0.829
Left elbow weighted scores of females: log(Y) transformation	0.108
Left elbow weighted scores of females: sqrt(Y) transformation	0.291
Left elbow weighted scores of females: 1/Y transformation	<0.001

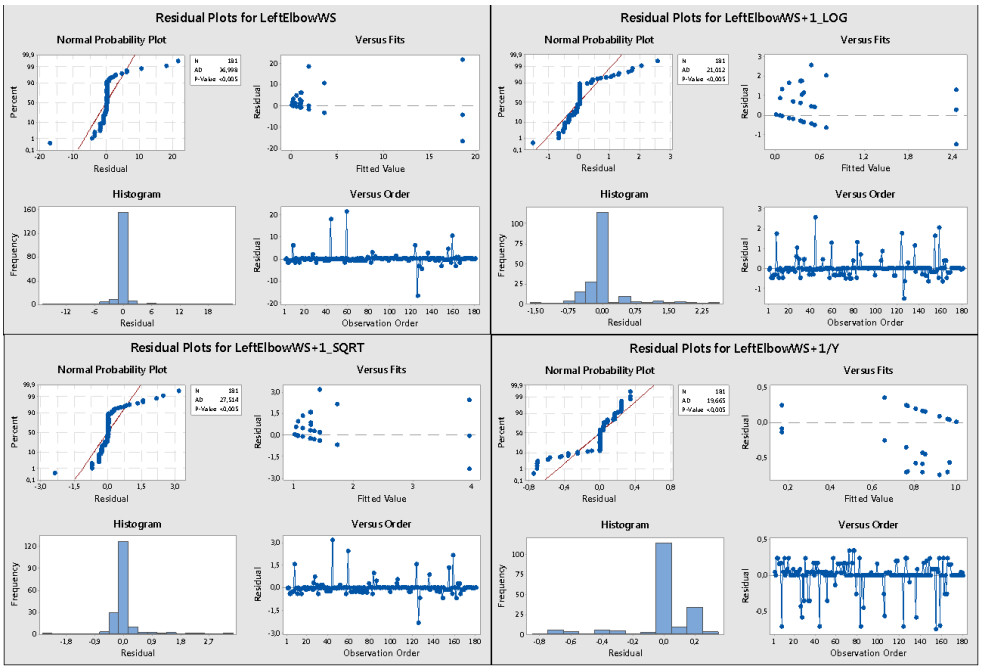


Figure D.36. The unsatisfied ANOVA assumptions of left elbow weighted scores of males

Table D.36. The Levene's Test results for left elbow weighted scores of males

Output	**Levene's Test Result**
Left elbow weighted scores of males	<0.001
Left elbow weighted scores of males: log(Y) transformation	0.066
Left elbow weighted scores of males: sqrt(Y) transformation	<0.001
Left elbow weighted scores of males: 1/Y transformation	0.006

Table D.37. The Levene's Test results for right pinkie weighted scores of females

Output	**Levene's Test Result**
Right pinkie weighted scores of females	0.350
Right pinkie weighted scores of females: log(Y) transformation	0.015
Right pinkie weighted scores of females: sqrt(Y) transformation	0.093
Right pinkie weighted scores of females: 1/Y transformation	0.013

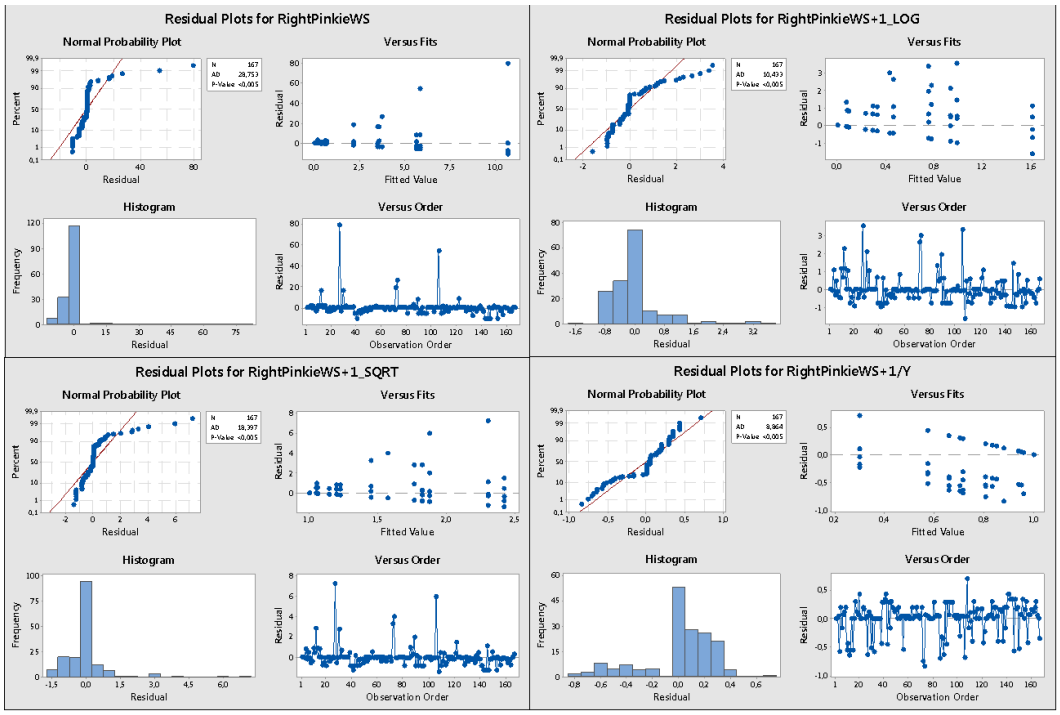


Figure D.37. The unsatisfied ANOVA assumptions of right pinkie weighted scores of females

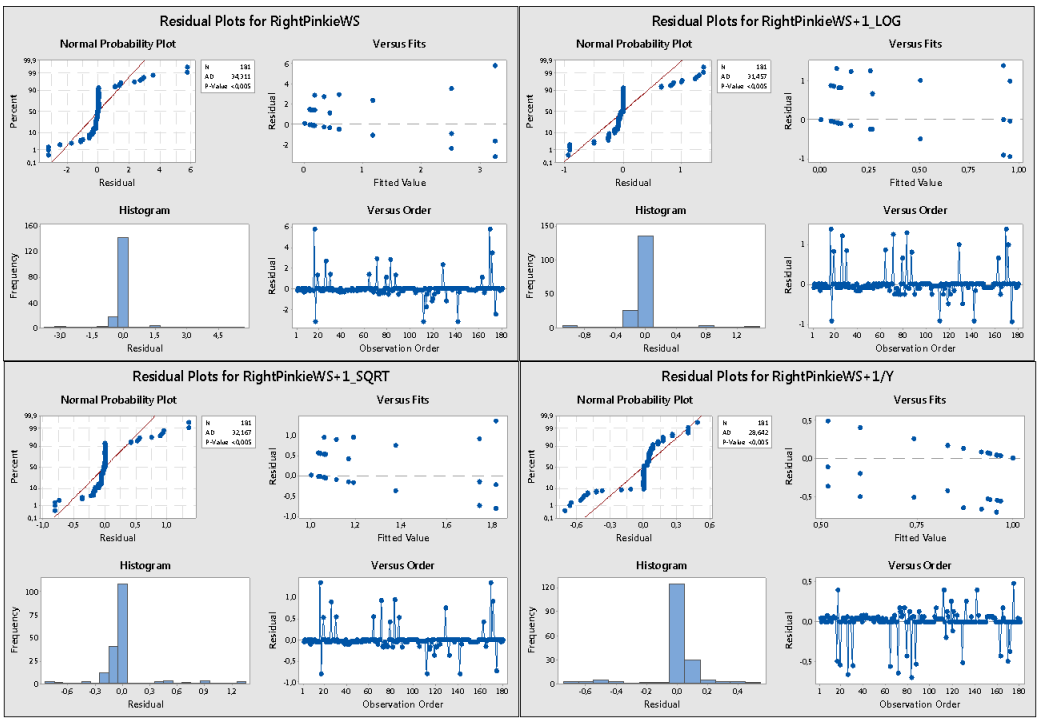
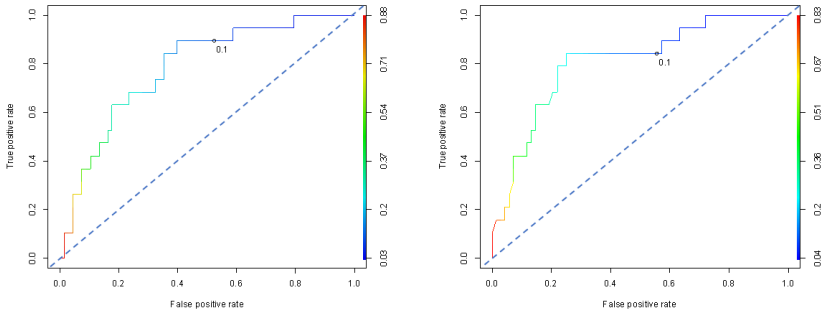


Figure D.38. The unsatisfied ANOVA assumptions of right pinkie weighted scores of males

Table D.38. The Levene's Test results for right pinkie weighted scores of males

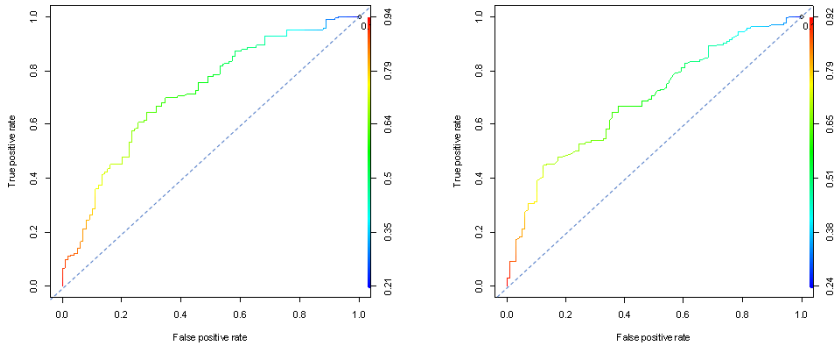
Output	**Levene's Test Result**
Right pinkie weighted scores of males	<0.001
Right pinkie weighted scores of males: log(Y) transformation	<0.001
Right pinkie weighted scores of males: sqrt(Y) transformation	<0.001
Right pinkie weighted scores of males: 1/Y transformation	<0.001

APPENDIX E: ROC CURVES AND CORRELATIONS OF HAND DIMENSIONS



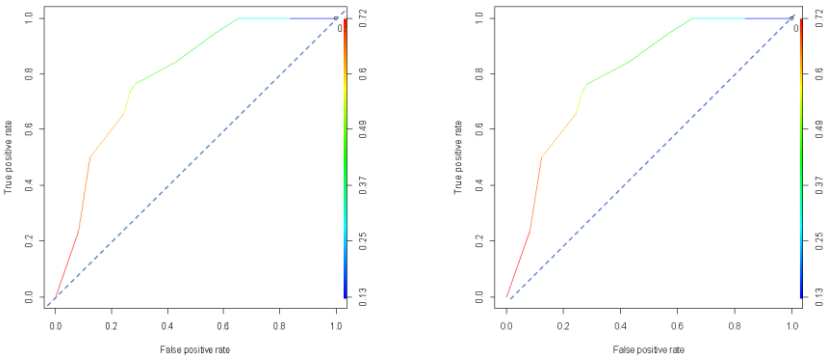
(a) (b)

Figure E.1. ROC Curves of Ears Prevalence Model-1 (a) and Model-2 (b)



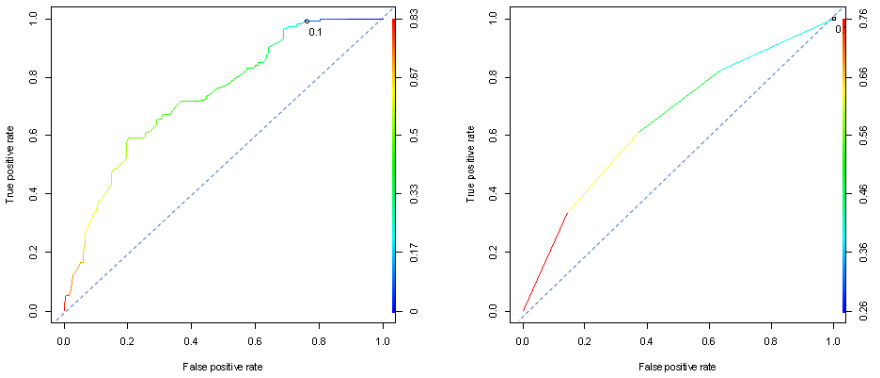
(a) (b)

Figure E.2. ROC Curves of Neck Prevalence Model-1 (a) and Model-2 (b)



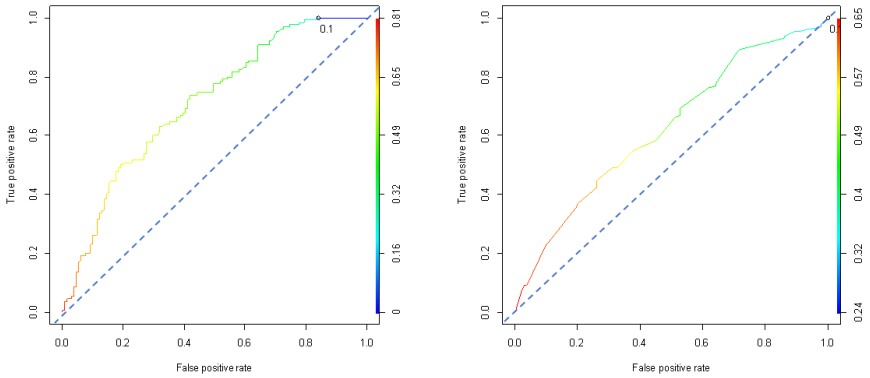
(a) (b)

Figure E.3. ROC Curves of Right Shoulder Prevalence Model-1 (a) and Model-2 (b)



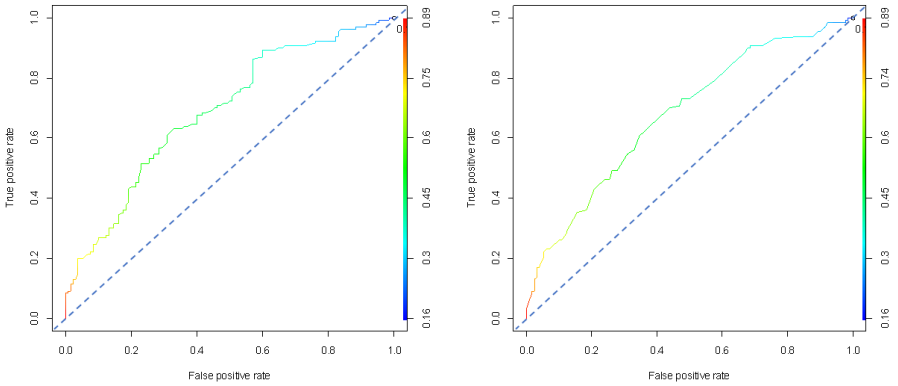
(a) (b)

Figure E.4. ROC Curves of Left Shoulder Prevalence Model-1 (a) and Model-2 (b)



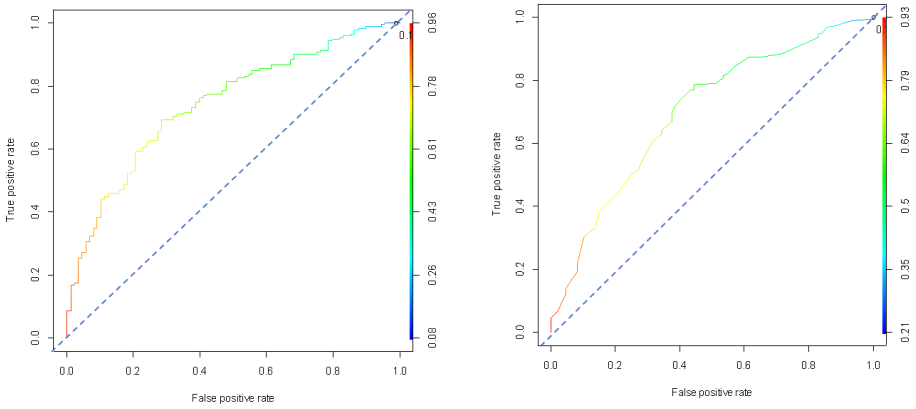
(a) (b)

Figure E.5. ROC Curves of Upper Back Prevalence Model-1 (a) and Model-2 (b)



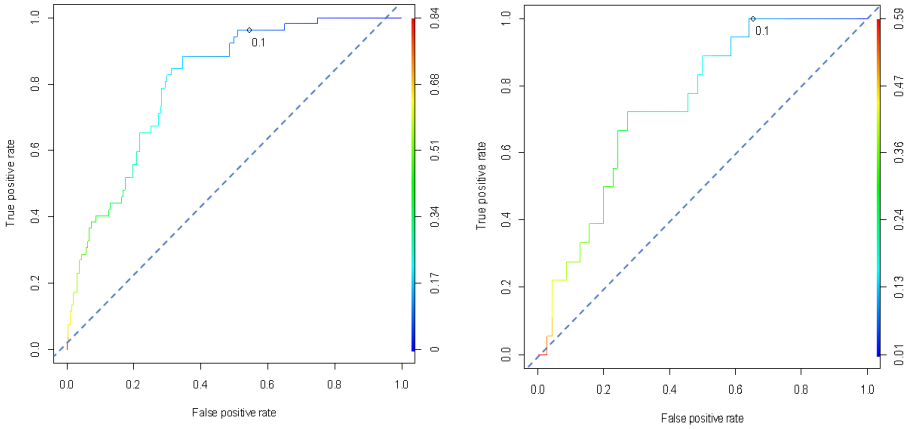
(a) (b)

Figure E.6. ROC Curves of Lower Back Prevalence Model-1 (a) and Model-2 (b)



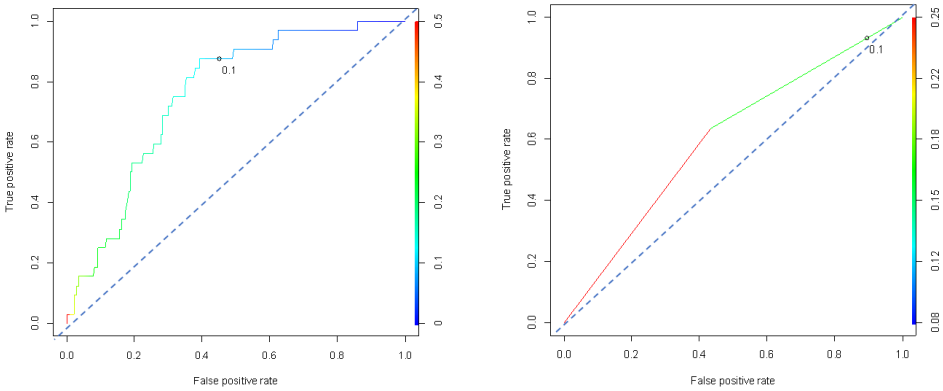
(a) (b)

Figure E.7. ROC Curves of Total Body Performance Effect Model-1 (a) and Model-2 (b)



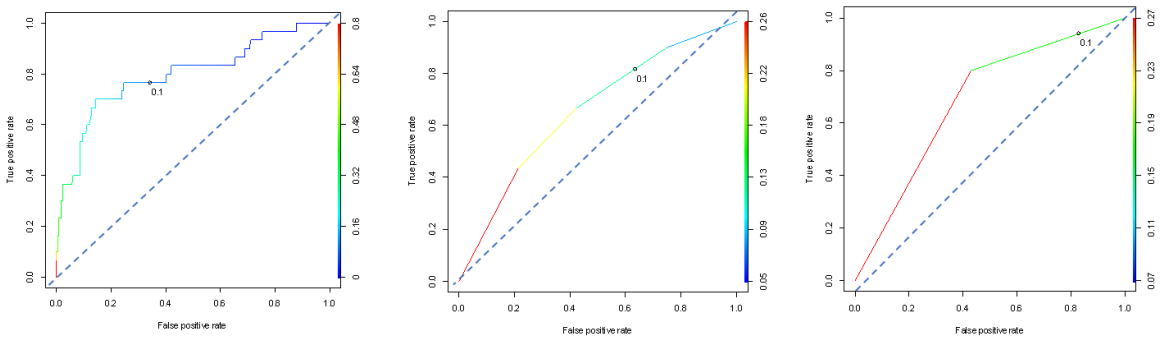
(a) (b)

Figure E.8. ROC Curves of Neck Performance Effect Model-1 (a) and Model-2 (b)



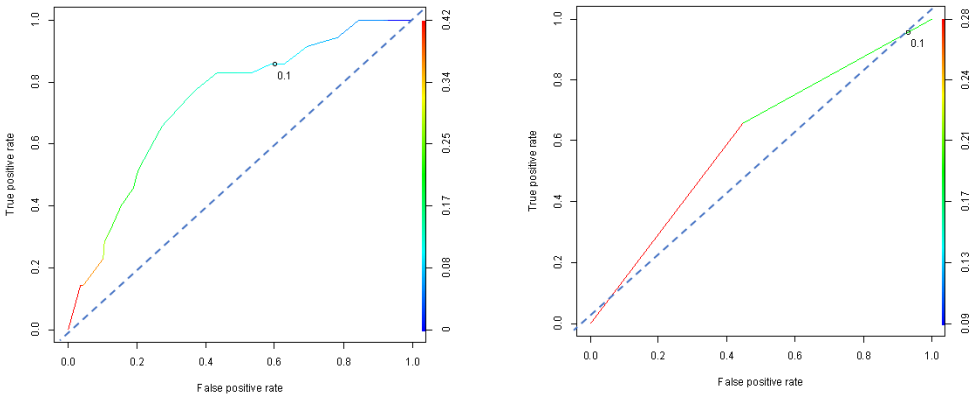
(a) (b)

Figure E.9. ROC Curves of Right Shoulder Performance Effect Model-1 (a) and Model-2 (b)



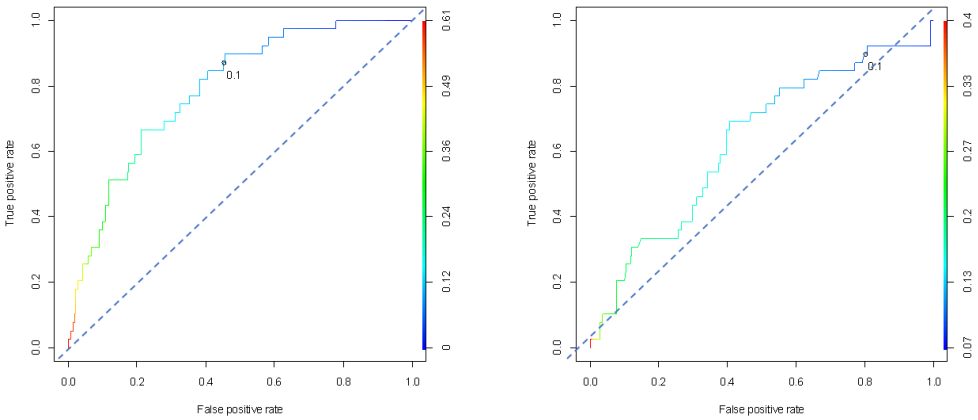
(a) (b) (c)

Figure E.10. ROC Curves of Left Shoulder Performance Effect Model-1 (a), Model-2 (b) and Model-3 (c)



(a) (b)

Figure E.11. ROC Curves of Upper Back Performance Effect Model-1 (a) and Model-2 (b)



(a) (b)

Figure E.12. ROC Curves of Lower Back Performance Effect Model-1 (a) and Model-2 (b)

Weigthed Scores	Cell Contents	Right HS	Left HS	Right-2-HS	Left-2-HS	RightH Breadth	RightH Length	LeftH Breadth	LeftH Length	Rthumb Length	Lthumb Length	RIndexF Length	LIndexF Length	RMiddleF Length	LMiddleF Length	RRingF Length	LRingF Length	RPinkie Length	LPinkie Length	RThumb Width	RIndexF Width	RMiddleF Width	RRingF Width	Rpinkie Width	Lthumb Width	LIndexF Width	LMiddleF Width	LRingF Width	Lpinkie Width
TOTALBODYWS	Corr. Coef.	-0,15	-0,049	-0,014	0,073	-0,231	0,035	-0,21	0,049	-0,114	-0,107	0,055	0,02	0,173	0,158	0,102	0,064	0,186	0,197	-0,147	-0,233	-0,201	-0,166	-0,048	-0,162	-0,233	-0,211	-0,196	-0,042
	p-value	0,405	0,786	0,939	0,685	0,196	0,848	0,241	0,786	0,528	0,555	0,76	0,912	0,336	0,381	0,572	0,724	0,3	0,272	0,415	0,192	0,262	0,356	0,792	0,369	0,192	0,238	0,275	0,817
NeckWS	Corr. Coef.	-0,146	-0,23	-0,043	-0,072	-0,118	-0,106	-0,117	-0,106	0,034	0,052	0,111	0,069	0,149	0,141	0,156	0,139	0,052	0,081	-0,05	-0,111	-0,107	-0,074	-0,039	-0,044	-0,111	-0,167	-0,098	0,014
	p-value	0,419	0,198	0,811	0,692	0,513	0,555	0,515	0,556	0,849	0,775	0,537	0,702	0,407	0,433	0,386	0,442	0,776	0,655	0,782	0,537	0,553	0,683	0,83	0,808	0,537	0,352	0,589	0,937
RightShoulderWS	Corr. Coef.	-0,135	-0,276	-0,015	0,027	-0,191	-0,324	-0,144	-0,323	-0,183	-0,179	-0,216	-0,192	-0,29	-0,301	-0,187	-0,225	-0,136	-0,098	-0,041	-0,128	-0,109	-0,06	-0,032	-0,006	-0,128	-0,177	-0,111	0,018
	p-value	0,454	0,12	0,935	0,881	0,287	0,066	0,423	0,067	0,308	0,32	0,227	0,284	0,101	0,089	0,297	0,208	0,45	0,588	0,82	0,477	0,547	0,74	0,86	0,973	0,477	0,324	0,537	0,919
LeftShoulderWS	Corr. Coef.	-0,149	-0,179	-0,018	-0,075	-0,086	-0,052	-0,093	-0,043	0,092	0,107	-0,006	-0,044	0,001	-0,022	-0,011	0,005	0,081	0,11	-0,141	-0,144	-0,171	-0,145	-0,103	-0,041	-0,144	-0,221	-0,144	-0,082
	p-value	0,408	0,319	0,92	0,678	0,635	0,772	0,607	0,81	0,611	0,553	0,972	0,806	0,996	0,903	0,954	0,978	0,653	0,542	0,435	0,424	0,343	0,419	0,567	0,819	0,424	0,216	0,426	0,648
UpperBackWS	Corr. Coef.	0,146	0,054	0,069	0,16	0,026	-0,061	0,012	-0,074	0,12	0,151	0,031	0,002	0,174	0,145	0,155	0,132	0,099	0,141	0,086	0,175	0,182	0,148	0,161	0,057	0,175	0,174	0,133	0,176
	p-value	0,416	0,766	0,703	0,374	0,884	0,734	0,949	0,682	0,505	0,403	0,862	0,993	0,333	0,421	0,39	0,466	0,585	0,434	0,634	0,331	0,311	0,412	0,37	0,752	0,331	0,332	0,46	0,327
LowerBackWS	Corr. Coef.	0,206	0,25	0,157	0,21	0,21	0,165	0,226	0,163	0,005	-0,002	0,048	0,028	0,164	0,158	-0,048	-0,07	-0,043	-0,059	0,006	0,104	0,11	0,305	0,159	-0,062	0,104	0,095	0,322	0,156
	p-value	0,251	0,161	0,382	0,242	0,241	0,358	0,206	0,366	0,979	0,992	0,791	0,877	0,363	0,379	0,79	0,698	0,812	0,745	0,974	0,565	0,542	0,084	0,377	0,731	0,565	0,598	0,067	0,387
RightThumbWS	Corr. Coef.	-0,02	0,094	0,014	0,104	-0,069	-0,049	-0,068	-0,049	-0,125	-0,122	0,05	0,055	0,056	0,045	0,088	0,073	0,144	0,162	-0,245	-0,179	-0,138	-0,048	-0,03	-0,246	-0,179	-0,143	-0,074	-0,011
	p-value	0,912	0,601	0,94	0,563	0,702	0,788	0,707	0,788	0,488	0,501	0,782	0,762	0,759	0,805	0,627	0,685	0,424	0,369	0,169	0,32	0,442	0,789	0,867	0,167	0,32	0,427	0,684	0,953
LeftThumbWS	Corr. Coef.	-0,228	-0,098	-0,126	-0,008	-0,216	-0,213	-0,218	-0,212	-0,122	-0,09	-0,016	0	0,258	0,24	0,148	0,158	-0,057	-0,028	-0,291	-0,294	-0,367	-0,365	-0,299	-0,3	-0,294	-0,307	-0,41	-0,295
	p-value	0,202	0,588	0,485	0,966	0,227	0,233	0,223	0,236	0,497	0,618	0,929	1	0,147	0,178	0,413	0,38	0,755	0,878	0,1	0,096	**0,036**	**0,037**	0,091	0,09	0,096	0,082	**0,018**	0,096
RightIndexFinger WS	Corr. Coef.	0,188	0,144	0	-0,094	0,094	0,094	0,1	0,122	0	0,011	0,233	0,2	0,205	0,216	0,194	0,183	0,033	0,033	-0,251	-0,112	-0,062	-0,034	-0,028	-0,241	-0,112	0	0	-0,023
	p-value	0,294	0,424	1	0,602	0,602	0,602	0,581	0,499	1	0,951	0,192	0,265	0,252	0,227	0,279	0,309	0,854	0,854	0,159	0,534	0,734	0,852	0,877	0,177	0,534	1	1	0,901
LeftIndexFingerWS	Corr. Coef.	-0,158	-0,025	0,03	0,154	-0,178	0,08	-0,18	0,115	0,104	0,117	-0,143	-0,125	0,026	0	-0,111	-0,116	-0,143	-0,09	-0,14	-0,08	-0,149	-0,174	-0,162	-0,113	-0,08	-0,129	-0,115	-0,12
	p-value	0,38	0,89	0,867	0,393	0,321	0,659	0,317	0,522	0,563	0,517	0,426	0,489	0,886	0,998	0,538	0,52	0,428	0,619	0,436	0,659	0,406	0,332	0,368	0,532	0,659	0,474	0,523	0,505
RightMiddleFingerWS	Corr. Coef.	0,186	0,186	0,065	0,056	-0,009	0,037	-0,037	0,037	-0,074	-0,093	0,242	0,242	0,279	0,279	0,26	0,269	0,261	0,251	-0,168	-0,019	0,038	-0,066	0,028	-0,169	-0,019	0,038	-0,085	0,038
	p-value	0,301	0,301	0,719	0,758	0,959	0,837	0,837	0,837	0,681	0,607	0,176	0,175	0,116	0,116	0,143	0,13	0,143	0,159	0,349	0,917	0,836	0,715	0,876	0,347	0,917	0,836	0,639	0,835
LeftMiddleFingerWS	Corr. Coef.	-0,131	0,058	0,004	0,083	0,009	0,152	-0,029	0,141	0,185	0,169	0,031	0,051	0,181	0,156	-0,037	0,005	-0,035	-0,014	0,153	0,154	0,072	-0,013	0,044	0,175	0,154	0,099	0,014	0,051
	p-value	0,468	0,748	0,983	0,648	0,961	0,4	0,875	0,434	0,303	0,347	0,862	0,779	0,312	0,385	0,839	0,98	0,845	0,939	0,395	0,392	0,689	0,941	0,807	0,33	0,392	0,585	0,94	0,778
RightRingFingerWS	Corr. Coef.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	p-value	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
LeftRingFingerWS	Corr. Coef.	-0,06	0,13	0,12	0,216	-0,022	0,2	-0,07	0,21	0,098	0,082	-0,071	-0,024	0,084	0,06	-0,084	-0,104	-0,062	-0,028	-0,005	0,062	-0,004	-0,046	-0,084	-0,022	0,062	0,009	-0,016	-0,076
	p-value	0,742	0,471	0,506	0,228	0,901	0,265	0,7	0,24	0,586	0,65	0,694	0,893	0,641	0,74	0,64	0,563	0,733	0,877	0,978	0,733	0,98	0,799	0,641	0,905	0,733	0,96	0,93	0,673
RightPinkieWS	Corr. Coef.	-0,392	-0,323	-0,441	-0,4	-0,213	-0,366	-0,234	-0,35	-0,09	-0,056	-0,199	-0,194	-0,052	-0,052	0,004	0,02	-0,122	-0,125	-0,304	-0,415	-0,377	-0,384	-0,416	-0,248	-0,415	-0,349	-0,401	-0,411
	p-value	**0,024**	0,067	**0,01**	**0,021**	0,233	**0,036**	0,189	**0,046**	0,617	0,755	0,268	0,28	0,772	0,772	0,984	0,912	0,5	0,487	0,085	**0,016**	**0,03**	**0,027**	**0,016**	0,164	**0,016**	**0,047**	**0,021**	**0,018**
LeftPinkieWS	Corr. Coef.	-0,334	-0,224	-0,296	-0,233	-0,072	-0,091	-0,086	-0,092	-0,01	0,021	-0,152	-0,143	0,135	0,098	0,001	0,018	-0,078	-0,061	-0,302	-0,263	-0,266	-0,227	-0,279	-0,228	-0,263	-0,253	-0,23	-0,27
	p-value	0,057	0,21	0,094	0,192	0,69	0,613	0,635	0,609	0,957	0,907	0,4	0,428	0,454	0,586	0,993	0,92	0,666	0,736	0,087	0,139	0,135	0,204	0,116	0,202	0,139	0,155	0,198	0,129
RightPalmWS	Corr. Coef.	-0,026	-0,057	-0,019	0,01	0,117	-0,081	0,131	-0,088	-0,089	-0,089	-0,031	-0,058	-0,222	-0,227	-0,116	-0,152	0,111	0,111	0,145	0,161	0,142	0,142	0,215	0,137	0,161	0,128	0,129	0,222
	p-value	0,886	0,755	0,918	0,957	0,515	0,653	0,468	0,626	0,622	0,624	0,863	0,747	0,215	0,204	0,52	0,4	0,537	0,539	0,421	0,37	0,432	0,43	0,23	0,446	0,37	0,477	0,474	0,215
LeftPalmWS	Corr. Coef.	-0,134	-0,183	-0,044	-0,025	-0,013	-0,26	-0,012	-0,255	-0,016	-0,027	-0,126	-0,15	-0,12	-0,101	-0,056	-0,023	-0,002	-0,036	-0,042	-0,193	-0,189	-0,195	-0,18	-0,063	-0,193	-0,211	-0,229	-0,181
	p-value	0,456	0,309	0,806	0,889	0,941	0,144	0,945	0,152	0,929	0,882	0,485	0,406	0,505	0,576	0,756	0,899	0,99	0,844	0,815	0,281	0,293	0,276	0,315	0,726	0,281	0,238	0,2	0,314
RightBottomofThumbWS	Corr. Coef.	0,104	0,093	0,038	0,082	-0,205	-0,043	-0,18	-0,029	0,01	-0,005	0,033	0,051	0,225	0,201	0,096	0,108	0,272	0,273	-0,325	-0,26	-0,229	-0,303	-0,19	-0,312	-0,26	-0,248	-0,302	-0,13
	p-value	0,566	0,607	0,835	0,65	0,251	0,813	0,316	0,871	0,956	0,977	0,854	0,776	0,209	0,261	0,595	0,551	0,126	0,125	0,065	0,144	0,2	0,086	0,29	0,077	0,144	0,164	0,087	0,469
LeftBottomofThumbWS	Corr. Coef.	-0,074	0,04	-0,088	-0,009	-0,209	-0,074	-0,202	-0,071	-0,2	-0,2	-0,018	0,01	0,246	0,249	0,071	0,077	0,052	0,036	-0,296	-0,309	-0,314	-0,399	-0,327	-0,338	-0,309	-0,291	-0,415	-0,319
	p-value	0,68	0,824	0,625	0,96	0,242	0,681	0,26	0,695	0,265	0,264	0,92	0,954	0,168	0,162	0,696	0,669	0,773	0,843	0,094	0,08	0,075	**0,021**	0,063	0,054	0,08	0,101	**0,016**	0,07

* Green colored cells indicate significant positive correlation while orange colored cells indicate significant negative correlation

Figure E.13. Hand dimension correlations before Ratio Scaling

Weigthed Scores	Cell Contents	RightHS	LeftHS	Right2HS	Left2HS	RightHBreadth	RightHLength	LeftHBreadth	LeftHLength	RThumbTotal	LThumbTotal	RIndexFTotal	LIndexFTotal	RMiddleFTotal	LMiddleFTotal	RRingFTotal	LRingFTotal	RPinkieTotal	LPinkieTotal	RThumbWidth	RIndexFWidth	RMiddleFWidth	RRingFWidth	RPinkieWidth	LThumbWidth	LIndexFWidth	LMiddleFWidth	LRingFWidth	LPinkieWidth
NeckWS	Corr. Coef.	0,449	0,363	0,404	0,344	0,275	0,415	0,275	0,419	0,435	0,435	0,407	0,433	0,386	0,352	0,446	0,446	0,364	0,396	0,214	0,256	0,251	0,157	0,182	0,224	0,256	0,219	0,182	0,194
	p-value	**0,032**	0,089	0,056	0,108	0,204	**0,049**	0,204	**0,047**	**0,038**	**0,038**	0,054	**0,039**	0,069	0,099	**0,033**	**0,033**	0,088	0,061	0,327	0,238	0,249	0,475	0,406	0,303	0,238	0,315	0,406	0,376
RightShoulderWS	Corr. Coef.	-0,105	-0,058	-0,012	-0,012	-0,221	-0,058	-0,198	-0,058	-0,105	-0,105	-0,105	-0,058	-0,105	-0,105	-0,151	-0,175	-0,058	-0,035	-0,244	-0,244	-0,198	-0,244	-0,221	-0,268	-0,244	-0,221	-0,221	-0,221
	p-value	0,634	0,792	0,958	0,958	0,311	0,792	0,365	0,792	0,634	0,634	0,634	0,792	0,634	0,634	0,491	0,426	0,792	0,874	0,261	0,261	0,365	0,261	0,311	0,217	0,261	0,311	0,311	0,311
LeftShoulderWS	Corr. Coef.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	p-value	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
UpperBackWS	Corr. Coef.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	p-value	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
LowerBackWS	Corr. Coef.	-0,268	-0,224	-0,135	-0,149	-0,405	-0,282	-0,409	-0,282	-0,152	-0,152	-0,284	-0,247	-0,214	-0,214	-0,297	-0,311	-0,085	-0,12	-0,393	-0,415	-0,455	-0,422	-0,444	-0,372	-0,415	-0,407	-0,444	-0,417
	p-value	0,216	0,305	0,539	0,499	0,055	0,193	0,053	0,193	0,488	0,488	0,19	0,256	0,327	0,327	0,169	0,149	0,7	0,587	0,063	**0,049**	**0,029**	**0,045**	**0,034**	0,08	**0,049**	0,054	**0,034**	**0,048**
RightThumbWS	Corr. Coef.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	p-value	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
LeftThumbWS	Corr. Coef.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	p-value	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
RightIndexFingerWS	Corr. Coef.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	p-value	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
LeftIndexFingerWS	Corr. Coef.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	p-value	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
RightMiddleFingerWS	Corr. Coef.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	p-value	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
LeftMiddleFingerWS	Corr. Coef.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	p-value	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
RightRingFingerWS	Corr. Coef.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	p-value	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
LeftRingFingerWS	Corr. Coef.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	p-value	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
RightPinkieWS	Corr. Coef.	-0,062	-0,1	0,011	-0,042	-0,26	-0,009	-0,26	0,009	-0,085	-0,085	-0,011	-0,029	-0,024	-0,006	-0,125	-0,125	-0,11	-0,093	-0,298	-0,222	-0,204	-0,242	-0,222	-0,298	-0,222	-0,24	-0,222	-0,26
	p-value	0,778	0,649	0,959	0,85	0,231	0,968	0,231	0,968	0,7	0,7	0,959	0,895	0,913	0,977	0,568	0,568	0,616	0,675	0,167	0,309	0,35	0,266	0,309	0,167	0,309	0,271	0,309	0,231
LeftPinkieWS	Corr. Coef.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	p-value	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
RightPalmWS	Corr. Coef.	-0,14	-0,14	-0,002	-0,061	-0,368	-0,049	-0,351	-0,035	-0,145	-0,145	-0,08	-0,06	-0,106	-0,091	-0,207	-0,222	-0,136	-0,104	-0,415	-0,349	-0,306	-0,368	-0,353	-0,43	-0,349	-0,349	-0,353	-0,368
	p-value	0,524	0,524	0,993	0,782	0,084	0,823	0,101	0,874	0,508	0,508	0,718	0,787	0,631	0,679	0,343	0,309	0,537	0,636	**0,049**	0,102	0,156	0,084	0,098	**0,041**	0,102	0,102	0,098	0,084
LeftPalmWS	Corr. Coef.	-0,006	0,002	0,076	0,06	-0,197	0,05	-0,176	0,05	-0,041	-0,041	0,026	0,068	0,029	0,029	-0,067	-0,085	-0,009	0,012	-0,234	-0,197	-0,16	-0,215	-0,197	-0,253	-0,197	-0,178	-0,197	-0,197
	p-value	0,979	0,994	0,73	0,786	0,368	0,821	0,422	0,821	0,854	0,854	0,906	0,756	0,896	0,896	0,762	0,699	0,966	0,957	0,282	0,368	0,467	0,323	0,368	0,245	0,368	0,416	0,368	0,368
RightBottomofThumbWS	Corr. Coef.	0,084	-0,012	0,057	0,002	0,146	0,188	0,146	0,181	0,038	0,038	0,188	0,153	0,088	0,071	0,118	0,128	-0,152	-0,116	0,099	0,181	0,24	0,165	0,181	0,073	0,181	0,173	0,181	0,157
	p-value	0,704	0,955	0,796	0,993	0,506	0,39	0,506	0,407	0,862	0,862	0,39	0,487	0,689	0,748	0,592	0,559	0,49	0,597	0,654	0,407	0,271	0,452	0,407	0,74	0,407	0,429	0,407	0,475
LeftBottomofThumbWS	Corr. Coef.	-0,05	-0,119	-0,102	-0,118	0,064	0,02	0,064	0,002	-0,097	-0,097	-0,009	-0,034	-0,076	-0,095	-0,03	-0,019	-0,201	-0,176	0,032	0,083	0,132	0,072	0,089	0,005	0,083	0,086	0,089	0,075
	p-value	0,82	0,588	0,645	0,592	0,773	0,926	0,773	0,994	0,66	0,66	0,968	0,876	0,729	0,666	0,893	0,933	0,357	0,423	0,884	0,705	0,548	0,743	0,685	0,983	0,705	0,697	0,685	0,735
TOTALBODYWS	Corr. Coef.	0,131	-0,02	-0,091	-0,101	0,208	0,034	0,205	0,032	0,286	0,286	0,165	0,19	0,154	0,138	0,288	0,301	0,253	0,27	0,208	0,222	0,198	0,171	0,171	0,242	0,222	0,198	0,171	0,192
	p-value	0,551	0,927	0,679	0,647	0,34	0,877	0,347	0,886	0,186	0,186	0,451	0,386	0,482	0,531	0,182	0,163	0,243	0,212	0,341	0,308	0,366	0,435	0,436	0,267	0,308	0,366	0,436	0,381

* Green colored cells indicate significant positive correlation while orange colored cells indicate significant negative correlation

Figure E.14. Brass instruments players' hand dimension correlations after Ratio Scaling

Weigthed Scores	Cell Contents	RightHS	LeftHS	Right2HS	Left2HS	RightHBreadth	RightHLength	LeftHBreadth	LeftHLength	RThumbTotal	LThumbTotal	RIndexFTotal	LIndexFTotal	RMiddleFTotal	LMiddleFTotal	RRingFTotal	LRingFTotal	RPinkieTotal	LPinkieTotal	RThumbWidth	RIndexFWidth	RMiddleFWidth	RRingFWidth	RPinkieWidth	LThumbWidth	LIndexFWidth	LMiddleFWidth	LRingFWidth	LPinkieWidth
NeckWS	p-value	-0,15	-0,129	-0,262	-0,252	0,374	-0,181	0,299	-0,192	0,189	0,164	-0,117	-0,131	-0,103	-0,112	0,106	0,147	0,134	0,114	0,448	0,415	0,279	0,437	0,347	0,522	0,415	0,39	0,352	0,397
	Corr. Coef.	0,42	0,49	0,155	0,172	**0,038**	0,33	0,102	0,302	0,308	0,379	0,532	0,481	0,582	0,55	0,569	0,431	0,473	0,54	**0,011**	**0,02**	0,129	**0,014**	0,056	**0,003**	**0,02**	**0,03**	0,052	**0,027**
RightShoulderWS	p-value	-0,166	-0,168	-0,272	-0,17	0,313	-0,057	0,314	-0,018	-0,2	-0,212	-0,016	-0,127	-0,099	-0,108	0,026	0,013	-0,107	-0,17	0,34	0,34	0,34	0,366	0,38	0,312	0,34	0,353	0,354	0,379
	Corr. Coef.	0,373	0,366	0,139	0,36	0,087	0,762	0,086	0,925	0,28	0,253	0,931	0,498	0,595	0,562	0,891	0,946	0,568	0,361	0,061	0,061	0,061	**0,043**	**0,035**	0,087	0,061	0,052	0,051	**0,035**
LeftShoulderWS	p-value	0,265	0,211	0,17	0,118	0,108	0,267	0,108	0,267	-0,041	-0,052	0,224	0,179	0,289	0,291	0,156	0,119	-0,231	-0,206	0,011	0,148	0,136	0,049	0,061	0,011	0,148	0,111	0,061	0,061
	Corr. Coef.	0,15	0,254	0,36	0,529	0,563	0,146	0,563	0,146	0,827	0,78	0,226	0,337	0,115	0,112	0,401	0,525	0,212	0,267	0,953	0,426	0,467	0,794	0,743	0,953	0,426	0,554	0,743	0,743
UpperBackWS	p-value	-0,002	0,002	-0,055	-0,098	-0,065	-0,008	-0,055	-0,011	-0,066	-0,053	0,049	0,036	0,15	0,182	-0,031	-0,065	-0,317	-0,288	-0,153	-0,019	-0,117	-0,171	-0,165	-0,159	-0,019	-0,075	-0,182	-0,139
	Corr. Coef.	0,99	0,993	0,768	0,598	0,73	0,967	0,769	0,953	0,725	0,775	0,792	0,849	0,42	0,327	0,867	0,73	0,083	0,116	0,41	0,92	0,532	0,357	0,375	0,394	0,92	0,688	0,328	0,457
LowerBackWS	p-value	0,071	0,059	0,074	0,007	-0,003	-0,02	0,001	-0,031	0,148	0,147	0,104	0,139	-0,013	0,007	0,166	0,153	-0,112	-0,098	-0,148	-0,012	0,043	0,017	-0,036	-0,133	-0,012	0,033	0,049	0,045
	Corr. Coef.	0,704	0,753	0,691	0,972	0,985	0,914	0,994	0,868	0,427	0,429	0,577	0,457	0,944	0,972	0,373	0,411	0,548	0,601	0,426	0,947	0,819	0,929	0,847	0,474	0,947	0,862	0,795	0,811
RightThumbWS	p-value	0,113	0,246	0,278	0,312	-0,052	0,21	0,036	0,21	-0,074	-0,076	0,066	0,139	0,031	0,087	0,102	0,039	0,349	0,348	-0,229	-0,289	-0,219	-0,141	-0,141	-0,275	-0,289	-0,271	-0,148	-0,135
	Corr. Coef.	0,546	0,183	0,13	0,087	0,779	0,258	0,848	0,258	0,692	0,686	0,725	0,456	0,869	0,642	0,584	0,835	0,054	0,055	0,216	0,115	0,236	0,448	0,448	0,135	0,115	0,14	0,428	0,47
LeftThumbWS	p-value	0,095	0,213	0,154	0,198	-0,11	0,037	-0,081	0,037	0,007	0,022	-0,125	-0,066	0,125	0,154	-0,095	-0,11	0,228	0,242	-0,169	-0,228	-0,272	-0,272	-0,272	-0,154	-0,228	-0,272	-0,272	-0,272
	Corr. Coef.	0,61	0,25	0,408	0,285	0,555	0,845	0,666	0,845	0,969	0,906	0,503	0,724	0,503	0,407	0,61	0,555	0,218	0,189	0,364	0,218	0,139	0,139	0,139	0,408	0,218	0,139	0,139	0,139
RightIndexFingerWS	p-value	-0,151	-0,131	-0,122	-0,142	-0,251	-0,236	-0,24	-0,226	-0,119	-0,097	-0,289	-0,248	-0,219	-0,188	-0,27	-0,26	-0,095	-0,061	-0,282	-0,262	-0,2	-0,205	-0,231	-0,247	-0,262	-0,221	-0,122	-0,226
	Corr. Coef.	0,416	0,481	0,512	0,447	0,174	0,201	0,193	0,222	0,524	0,605	0,114	0,179	0,236	0,312	0,142	0,159	0,61	0,743	0,125	0,154	0,281	0,268	0,211	0,181	0,154	0,233	0,513	0,222
LeftIndexFingerWS	p-value	-0,145	-0,078	-0,067	-0,042	-0,374	-0,217	-0,327	-0,205	-0,274	-0,249	-0,383	-0,348	-0,293	-0,257	-0,396	-0,396	-0,189	-0,151	-0,409	-0,387	-0,293	-0,322	-0,352	-0,393	-0,387	-0,34	-0,228	-0,346
	Corr. Coef.	0,436	0,677	0,719	0,821	**0,038**	0,241	0,073	0,268	0,136	0,177	**0,033**	0,055	0,11	0,162	**0,027**	**0,027**	0,309	0,418	**0,022**	**0,031**	0,11	0,077	0,052	**0,029**	**0,031**	0,061	0,218	0,057
RightMiddleFingerWS	p-value	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	Corr. Coef.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
LeftMiddleFingerWS	p-value	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	Corr. Coef.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
RightRingFingerWS	p-value	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	Corr. Coef.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
LeftRingFingerWS	p-value	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	Corr. Coef.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
RightPinkieWS	p-value	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	Corr. Coef.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
LeftPinkieWS	p-value	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	Corr. Coef.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
RightPalmWS	p-value	-0,202	-0,14	-0,284	-0,202	0,283	-0,132	0,258	-0,128	-0,136	-0,15	-0,17	-0,227	-0,094	-0,081	-0,071	-0,076	-0,042	-0,088	0,286	0,279	0,191	0,278	0,254	0,298	0,279	0,257	0,243	0,263
	Corr. Coef.	0,276	0,454	0,121	0,275	0,123	0,48	0,162	0,493	0,465	0,42	0,36	0,219	0,616	0,663	0,705	0,683	0,823	0,638	0,119	0,129	0,303	0,129	0,168	0,104	0,129	0,163	0,187	0,153
LeftPalmWS	p-value	0,118	0,267	0,124	0,177	0,218	0,128	0,239	0,087	-0,217	-0,23	-0,183	-0,199	0,096	0,093	-0,105	-0,115	-0,061	-0,05	0,111	0,102	0,073	0,062	0,062	0,102	0,102	0,073	0,062	0,062
	Corr. Coef.	0,528	0,146	0,507	0,342	0,239	0,492	0,196	0,643	0,24	0,214	0,323	0,282	0,609	0,62	0,573	0,538	0,745	0,79	0,551	0,583	0,695	0,742	0,742	0,586	0,583	0,695	0,742	0,742
RightBottomofThumbWS	p-value	0,134	0,305	0,171	0,281	-0,098	0	-0,098	0,012	0,037	0,061	-0,11	-0,061	0,22	0,22	-0,085	-0,073	0,281	0,293	-0,195	-0,244	-0,33	-0,329	-0,33	-0,183	-0,244	-0,33	-0,329	-0,33
	Corr. Coef.	0,472	0,095	0,358	0,126	0,601	1	0,601	0,948	0,845	0,744	0,556	0,744	0,235	0,235	0,648	0,695	0,126	0,11	0,293	0,186	0,07	0,07	0,07	0,324	0,186	0,07	0,07	0,07
LeftBottomofThumbWS	p-value	-0,049	0,122	0,024	0,098	0,024	-0,037	0,024	-0,073	-0,171	-0,171	-0,256	-0,244	-0,061	-0,061	-0,232	-0,232	-0,024	-0,024	-0,061	-0,073	-0,11	-0,11	-0,11	-0,073	-0,073	-0,11	-0,11	-0,11
	Corr. Coef.	0,794	0,513	0,896	0,601	0,896	0,845	0,896	0,695	0,358	0,358	0,164	0,186	0,744	0,744	0,209	0,209	0,896	0,896	0,744	0,695	0,556	0,556	0,556	0,695	0,695	0,556	0,556	0,556
TOTALBODYWS	p-value	-0,055	0,109	0,087	0,148	-0,036	0,081	-0,001	0,102	-0,2	-0,203	0,002	-0,022	-0,04	-0,029	-0,005	-0,051	0,206	0,163	-0,015	-0,16	-0,109	-0,045	0,002	-0,045	-0,16	-0,124	-0,067	-0,036
		0,767	0,56	0,643	0,426	0,846	0,667	0,997	0,585	0,28	0,274	0,99	0,907	0,829	0,876	0,979	0,783	0,267	0,38	0,935	0,389	0,561	0,811	0,991	0,809	0,389	0,508	0,721	0,85

* Green colored cells indicate significant positive correlation while orange colored cells indicate significant negative correlation

Figure E.15. Drums and percussion instruments players' hand dimension correlations after Ratio Scaling

Weigthed Scores	Cell Contents	RightHS	LeftHS	Right2HS	Left2HS	RightHBreadth	RightHLength	LeftHBreadth	LeftHLength	RThumbTotal	LThumbTotal	RIndexFTotal	LIndexFTotal	RMiddleFTotal	LMiddleFTotal	RRingFTotal	LRingFTotal	RPinkieTotal	LPinkieTotal	RThumbWidth	RIndexFWidth	RMiddleFWidth	RRingFWidth	RPinkieWidth	LThumbWidth	LIndexFWidth	LMiddleFWidth	LRingFWidth	LPinkieWidth
NeckWS	Corr. Coef.	-0,218	-0,354	-0,027	-0,157	-0,205	-0,136	-0,184	-0,143	-0,308	-0,306	-0,186	-0,239	-0,261	-0,263	-0,168	-0,202	-0,052	-0,044	-0,07	-0,192	-0,164	-0,127	-0,029	-0,028	-0,192	-0,237	-0,118	-0,013
	p-value	0,067	**0,002**	0,822	0,192	0,087	0,258	0,124	0,233	**0,009**	**0,009**	0,121	**0,045**	**0,028**	**0,027**	0,16	0,091	0,665	0,719	0,56	0,108	0,171	0,293	0,811	0,819	0,108	**0,047**	0,326	0,914
RightShoulderWS	Corr. Coef.	-0,21	-0,201	-0,128	-0,18	-0,208	-0,28	-0,19	-0,278	-0,239	-0,242	-0,202	-0,196	-0,32	-0,288	-0,245	-0,231	-0,226	-0,215	-0,077	-0,159	-0,15	-0,171	-0,142	-0,062	-0,159	-0,176	-0,164	-0,137
	p-value	0,079	0,094	0,289	0,134	0,082	**0,018**	0,112	**0,019**	**0,045**	**0,042**	0,092	0,101	**0,007**	**0,015**	**0,04**	0,052	0,058	0,072	0,526	0,187	0,211	0,155	0,239	0,607	0,187	0,141	0,172	0,253
LeftShoulderWS	Corr. Coef.	-0,284	-0,292	-0,186	-0,261	-0,28	-0,225	-0,261	-0,223	-0,231	-0,231	-0,178	-0,223	-0,227	-0,202	-0,17	-0,162	-0,122	-0,108	-0,213	-0,303	-0,302	-0,282	-0,206	-0,181	-0,303	-0,315	-0,271	-0,196
	p-value	**0,016**	**0,013**	0,121	**0,028**	**0,018**	0,059	**0,028**	0,062	0,053	0,053	0,138	0,062	0,057	0,092	0,157	0,176	0,312	0,37	0,075	**0,01**	**0,01**	**0,017**	0,085	0,131	**0,01**	**0,007**	**0,022**	0,101
UpperBackWS	Corr. Coef.	0,039	0,173	-0,125	-0,026	-0,021	0,104	-0,009	0,123	0,141	0,176	0,061	0,065	0,161	0,176	0,08	0,087	0,091	0,102	-0,056	-0,069	-0,051	-0,138	-0,108	-0,079	-0,069	0,008	-0,116	-0,11
	p-value	0,746	0,15	0,299	0,829	0,864	0,39	0,94	0,306	0,24	0,143	0,616	0,59	0,179	0,142	0,509	0,469	0,452	0,398	0,641	0,568	0,674	0,251	0,368	0,51	0,568	0,947	0,336	0,36
LowerBackWS	Corr. Coef.	-0,152	-0,255	-0,052	-0,155	-0,127	-0,125	-0,136	-0,13	-0,168	-0,178	-0,207	-0,232	-0,165	-0,192	-0,207	-0,237	-0,121	-0,145	-0,083	-0,114	-0,103	-0,038	-0,007	-0,079	-0,114	-0,153	-0,035	-0,015
	p-value	0,205	**0,032**	0,665	0,196	0,29	0,299	0,257	0,279	0,161	0,138	0,084	0,052	0,169	0,109	0,084	**0,047**	0,313	0,228	0,49	0,344	0,394	0,755	0,952	0,513	0,344	0,202	0,773	0,902
RightThumbWS	Corr. Coef.	-0,264	-0,272	-0,142	-0,182	-0,29	-0,21	-0,288	-0,206	-0,294	-0,276	-0,207	-0,229	-0,144	-0,152	-0,16	-0,201	-0,157	-0,134	-0,295	-0,263	-0,265	-0,254	-0,208	-0,286	-0,263	-0,291	-0,264	-0,198
	p-value	**0,026**	**0,022**	0,238	0,129	**0,014**	0,079	**0,015**	0,085	**0,013**	**0,02**	0,083	0,055	0,231	0,206	0,183	0,093	0,192	0,264	**0,012**	**0,027**	**0,026**	**0,032**	0,081	**0,016**	**0,027**	**0,014**	**0,026**	0,098
LeftThumbWS	Corr. Coef.	-0,121	-0,014	-0,246	-0,195	-0,139	0,009	-0,127	0,024	-0,066	-0,032	-0,01	-0,033	0,097	0,105	0,012	0,011	0,026	0,036	-0,271	-0,238	-0,238	-0,275	-0,244	-0,245	-0,238	-0,168	-0,267	-0,232
	p-value	0,314	0,905	**0,039**	0,103	0,248	0,943	0,293	0,84	0,586	0,788	0,931	0,788	0,42	0,383	0,92	0,926	0,828	0,766	**0,022**	**0,046**	**0,046**	**0,02**	**0,04**	**0,039**	**0,046**	0,162	**0,024**	0,051
RightIndexFingerWS	Corr. Coef.	0,087	0,083	-0,005	0,008	0,044	0,094	0,023	0,094	0,138	0,138	0,222	0,212	0,311	0,316	0,271	0,264	0,148	0,147	-0,102	0,035	-0,006	0,011	-0,002	-0,118	0,035	0,045	-0,009	0
	p-value	0,472	0,492	0,968	0,947	0,716	0,436	0,852	0,435	0,252	0,25	0,063	0,077	**0,008**	**0,007**	**0,022**	**0,026**	0,219	0,221	0,399	0,772	0,961	0,93	0,985	0,327	0,772	0,712	0,938	0,998
LeftIndexFingerWS	Corr. Coef.	-0,045	-0,028	-0,108	-0,109	-0,046	0,023	-0,049	0,025	0,057	0,062	0,07	0,058	0,144	0,152	0,107	0,105	0,006	0,007	-0,114	-0,071	-0,108	-0,074	-0,087	-0,116	-0,071	-0,058	-0,084	-0,084
	p-value	0,712	0,815	0,37	0,365	0,704	0,852	0,684	0,835	0,639	0,608	0,562	0,634	0,23	0,207	0,373	0,385	0,958	0,954	0,346	0,558	0,369	0,542	0,473	0,334	0,558	0,63	0,487	0,487
RightMiddleFingerWS	Corr. Coef.	0,056	0,071	0,002	0,04	-0,017	0,068	-0,04	0,068	0,073	0,076	0,18	0,168	0,292	0,295	0,225	0,214	0,095	0,105	-0,176	-0,024	-0,066	-0,056	-0,067	-0,194	-0,024	-0,011	-0,078	-0,064
	p-value	0,645	0,557	0,985	0,741	0,887	0,575	0,739	0,574	0,543	0,527	0,134	0,16	**0,013**	**0,013**	0,06	0,073	0,43	0,385	0,142	0,84	0,585	0,64	0,579	0,105	0,84	0,927	0,519	0,594
LeftMiddleFingerWS	Corr. Coef.	0,012	0,043	-0,102	-0,081	0,031	0,07	0,024	0,061	0,107	0,101	0,154	0,14	0,242	0,245	0,125	0,14	0,031	0,032	-0,015	0,021	-0,011	0,008	0,002	-0,018	0,021	0,036	-0,006	0,004
	p-value	0,919	0,72	0,4	0,504	0,8	0,562	0,843	0,616	0,376	0,401	0,199	0,245	**0,042**	**0,04**	0,3	0,245	0,797	0,789	0,902	0,861	0,93	0,946	0,988	0,881	0,861	0,768	0,964	0,974
RightRingFingerWS	Corr. Coef.	0,024	0,046	0,041	0,064	-0,015	0,056	-0,012	0,056	0,1	0,111	0,086	0,095	0,17	0,176	0,124	0,115	0,045	0,054	-0,069	-0,024	-0,059	-0,051	-0,074	-0,081	-0,024	-0,021	-0,053	-0,071
	p-value	0,845	0,701	0,736	0,594	0,898	0,641	0,918	0,641	0,409	0,355	0,477	0,433	0,155	0,141	0,304	0,341	0,71	0,655	0,57	0,843	0,624	0,675	0,54	0,503	0,843	0,861	0,66	0,556
LeftRingFingerWS	Corr. Coef.	-0,04	0,003	-0,052	-0,031	-0,072	0,02	-0,058	0,02	0,003	0,013	-0,001	0,004	0,06	0,068	0,019	0,016	-0,027	-0,019	-0,105	-0,093	-0,108	-0,111	-0,107	-0,105	-0,093	-0,077	-0,108	-0,104
	p-value	0,743	0,981	0,664	0,795	0,553	0,866	0,633	0,866	0,982	0,914	0,993	0,974	0,619	0,573	0,878	0,894	0,825	0,878	0,384	0,44	0,372	0,356	0,376	0,385	0,44	0,525	0,371	0,388
RightPinkieWS	Corr. Coef.	-0,174	-0,068	-0,249	-0,194	-0,119	-0,075	-0,113	-0,058	-0,119	-0,093	-0,078	-0,123	-0,041	-0,039	-0,083	-0,081	-0,055	-0,028	-0,214	-0,256	-0,264	-0,267	-0,253	-0,177	-0,256	-0,193	-0,255	-0,247
	p-value	0,147	0,572	**0,036**	0,105	0,322	0,536	0,348	0,63	0,322	0,441	0,519	0,305	0,736	0,75	0,489	0,504	0,649	0,814	0,073	**0,031**	**0,026**	**0,024**	**0,033**	0,139	**0,031**	0,106	**0,032**	**0,037**
LeftPinkieWS	Corr. Coef.	0,012	0,047	-0,164	-0,121	0,045	0,143	0,038	0,156	0,018	0,03	0,085	0,046	0,054	0,068	0,035	0,037	0,071	0,08	-0,035	-0,073	-0,056	-0,062	-0,037	-0,015	-0,073	0,018	-0,045	-0,039
	p-value	0,92	0,7	0,171	0,316	0,709	0,233	0,752	0,194	0,88	0,804	0,48	0,703	0,653	0,575	0,774	0,759	0,554	0,507	0,769	0,544	0,64	0,607	0,76	0,9	0,544	0,884	0,712	0,745
RightPalmWS	Corr. Coef.	0,173	0,183	0,196	0,214	0,119	0,147	0,117	0,147	0,267	0,278	0,206	0,206	0,286	0,29	0,199	0,204	0,21	0,225	0,039	0,092	0,026	0,05	0,026	0,03	0,092	0,08	0,037	0,03
	p-value	0,15	0,128	0,102	0,073	0,324	0,223	0,331	0,222	**0,024**	**0,019**	0,084	0,085	**0,016**	**0,014**	0,097	0,089	0,079	0,059	0,745	0,446	0,827	0,678	0,829	0,805	0,446	0,507	0,76	0,801
LeftPalmWS	Corr. Coef.	0,104	0,13	0,105	0,122	0,054	0,102	0,061	0,102	0,177	0,187	0,125	0,123	0,192	0,197	0,108	0,117	0,134	0,148	-0,01	0,019	-0,029	-0,015	-0,018	-0,01	0,019	0,019	-0,024	-0,014
	p-value	0,39	0,279	0,382	0,312	0,653	0,396	0,612	0,395	0,14	0,119	0,299	0,308	0,11	0,099	0,37	0,33	0,264	0,217	0,936	0,872	0,807	0,898	0,882	0,936	0,872	0,876	0,844	0,909
RightBottomofThumbWS	Corr. Coef.	0,288	0,25	0,178	0,17	0,271	0,27	0,267	0,27	0,264	0,275	0,276	0,257	0,264	0,258	0,262	0,264	0,412	0,413	0,178	0,212	0,187	0,171	0,208	0,184	0,212	0,232	0,179	0,217
	p-value	**0,015**	**0,036**	0,139	0,155	**0,022**	**0,023**	**0,024**	**0,023**	**0,026**	**0,02**	**0,02**	**0,03**	**0,026**	**0,03**	**0,027**	**0,026**	**0**	**0**	0,136	0,076	0,118	0,153	0,081	0,125	0,076	0,052	0,136	0,069
LeftBottomofThumbWS	Corr. Coef.	0,02	-0,084	0,124	0,048	-0,027	0	-0,032	-0,012	-0,024	-0,02	-0,006	-0,018	0,033	0,02	0,038	0,004	0,134	0,131	-0,029	0,018	-0,02	0,023	0,071	-0,028	0,018	-0,04	0,006	0,079
	p-value	0,869	0,489	0,301	0,691	0,823	0,997	0,793	0,921	0,841	0,868	0,96	0,881	0,787	0,865	0,754	0,973	0,267	0,277	0,813	0,884	0,868	0,849	0,556	0,816	0,884	0,74	0,959	0,514
TOTALBODYWS	Corr. Coef.	-0,082	-0,133	-0,05	-0,116	-0,144	-0,03	-0,135	-0,018	-0,126	-0,107	-0,013	-0,068	-0,019	-0,015	-0,043	-0,054	0,077	0,101	-0,156	-0,18	-0,175	-0,189	-0,078	-0,14	-0,18	-0,172	-0,181	-0,068
	p-value	0,496	0,27	0,679	0,334	0,231	0,807	0,263	0,882	0,294	0,374	0,912	0,57	0,872	0,904	0,72	0,652	0,526	0,402	0,194	0,132	0,145	0,114	0,517	0,243	0,132	0,152	0,132	0,571

* Green colored cells indicate significant positive correlation while orange colored cells indicate significant negative correlation

Figure E.16. Keyboard instruments players' hand dimension correlations after Ratio Scaling

Weigthed Scores	Cell Contents	RightHS	LeftHS	Right2HS	Left2HS	RightHBreadth	RightHLength	LeftHBreadth	LeftHLength	RThumbTotal	LThumbTotal	RIndexFTotal	LIndexFTotal	RMiddleFTotal	LMiddleFTotal	RRingFTotal	LRingFTotal	RPinkieTotal	LPinkieTotal	RThumbWidth	RIndexFWidth	RMiddleFWidth	RRingFWidth	RPinkieWidth	LThumbWidth	LIndexFWidth	LMiddleFWidth	LRingFWidth	LPinkieWidth
NeckWS	Corr. Coef.	-0,174	-0,239	-0,101	-0,112	-0,153	-0,19	-0,137	-0,204	-0,265	-0,261	-0,205	-0,249	-0,243	-0,254	-0,161	-0,178	-0,172	-0,172	-0,125	-0,184	-0,142	-0,107	-0,041	-0,08	-0,184	-0,197	-0,115	-0,034
	p-value	0,088	**0,018**	0,326	0,273	0,134	0,063	0,18	**0,045**	**0,009**	**0,01**	**0,044**	**0,014**	**0,017**	**0,012**	0,114	0,081	0,092	0,093	0,223	0,072	0,164	0,298	0,688	0,435	0,072	0,053	0,262	0,738
RightShoulderWS	Corr. Coef.	-0,191	-0,246	-0,095	-0,114	-0,278	-0,188	-0,271	-0,19	-0,225	-0,223	-0,157	-0,169	-0,133	-0,137	-0,189	-0,221	-0,256	-0,253	-0,26	-0,249	-0,224	-0,223	-0,194	-0,28	-0,249	-0,269	-0,218	-0,206
	p-value	0,06	**0,015**	0,355	0,265	**0,006**	0,065	**0,007**	0,062	**0,027**	**0,028**	0,124	0,098	0,193	0,182	0,064	**0,03**	**0,011**	**0,012**	**0,01**	**0,014**	**0,027**	**0,028**	0,057	**0,006**	**0,014**	**0,008**	**0,032**	**0,043**
LeftShoulderWS	Corr. Coef.	-0,265	-0,301	-0,21	-0,286	-0,285	-0,283	-0,271	-0,277	-0,192	-0,185	-0,204	-0,212	-0,208	-0,206	-0,223	-0,232	-0,197	-0,193	-0,284	-0,28	-0,252	-0,241	-0,192	-0,224	-0,28	-0,27	-0,226	-0,194
	p-value	**0,009**	**0,003**	**0,039**	**0,005**	**0,005**	**0,005**	**0,007**	**0,006**	0,06	0,069	**0,045**	**0,037**	**0,041**	**0,043**	**0,028**	**0,022**	0,053	0,058	**0,005**	**0,006**	**0,013**	**0,017**	0,06	**0,027**	**0,006**	**0,008**	**0,026**	0,056
UpperBackWS	Corr. Coef.	0,291	0,283	0,23	0,266	0,188	0,254	0,176	0,258	0,243	0,251	0,244	0,264	0,175	0,17	0,216	0,212	0,174	0,177	0,213	0,23	0,227	0,189	0,178	0,17	0,23	0,243	0,209	0,169
	p-value	**0,004**	**0,005**	**0,024**	**0,008**	0,065	**0,012**	0,084	**0,011**	**0,017**	**0,013**	**0,016**	**0,009**	0,087	0,097	**0,033**	**0,037**	0,088	0,082	**0,036**	**0,023**	**0,025**	0,064	0,081	0,096	**0,023**	**0,017**	**0,04**	0,098
LowerBackWS	Corr. Coef.	0,022	0,038	0,039	0,048	-0,044	-0,017	-0,043	-0,015	-0,062	-0,06	-0,044	-0,013	0,013	0,013	-0,06	-0,071	-0,033	-0,053	-0,056	-0,05	-0,037	-0,074	-0,07	-0,105	-0,05	-0,042	-0,054	-0,075
	p-value	0,827	0,714	0,704	0,64	0,668	0,872	0,676	0,885	0,543	0,562	0,669	0,898	0,896	0,9	0,561	0,487	0,75	0,605	0,586	0,624	0,716	0,474	0,493	0,307	0,624	0,685	0,597	0,468
RightThumbWS	Corr. Coef.	0,169	0,176	0,132	0,18	0,163	0,173	0,174	0,175	0,033	0,03	0,109	0,103	0,103	0,095	0,09	0,086	0,058	0,052	0,144	0,138	0,155	0,116	0,154	0,131	0,138	0,144	0,137	0,146
	p-value	0,098	0,085	0,197	0,078	0,111	0,091	0,088	0,086	0,752	0,771	0,29	0,314	0,316	0,357	0,379	0,404	0,57	0,612	0,161	0,176	0,128	0,256	0,133	0,2	0,176	0,16	0,18	0,154
LeftThumbWS	Corr. Coef.	-0,047	-0,003	-0,02	0,038	-0,034	0,025	-0,011	0,033	-0,08	-0,059	0,022	0,009	0,076	0,079	0,023	0,021	-0,017	-0,013	-0,046	-0,085	-0,113	-0,132	-0,081	-0,038	-0,085	-0,092	-0,128	-0,087
	p-value	0,646	0,979	0,843	0,714	0,737	0,809	0,912	0,747	0,434	0,567	0,83	0,933	0,46	0,44	0,822	0,838	0,869	0,901	0,657	0,409	0,271	0,197	0,431	0,715	0,409	0,37	0,21	0,398
RightIndexFingerWS	Corr. Coef.	0,197	0,203	0,125	0,101	0,151	0,142	0,135	0,146	0,308	0,316	0,258	0,284	0,28	0,286	0,245	0,253	0,221	0,214	0,081	0,134	0,087	0,109	0,067	0,055	0,134	0,152	0,106	0,061
	p-value	0,053	**0,046**	0,222	0,326	0,14	0,165	0,187	0,154	**0,002**	**0,002**	**0,011**	**0,005**	**0,006**	**0,005**	**0,015**	**0,013**	**0,03**	**0,035**	0,429	0,19	0,397	0,288	0,512	0,595	0,19	0,138	0,303	0,554
LeftIndexFingerWS	Corr. Coef.	0,06	0,176	0,073	0,139	0,09	0,114	0,082	0,125	0,142	0,134	0,08	0,125	0,166	0,177	0,081	0,119	0,063	0,058	0,106	0,163	0,098	0,034	0,009	0,094	0,163	0,152	0,042	0,006
	p-value	0,558	0,084	0,479	0,174	0,38	0,267	0,426	0,222	0,166	0,192	0,437	0,224	0,103	0,084	0,431	0,246	0,54	0,572	0,303	0,11	0,339	0,738	0,932	0,361	0,11	0,138	0,681	0,951
RightMiddleFingerWS	Corr. Coef.	0,094	0,115	0,094	0,092	0,055	0,054	0,04	0,059	0,19	0,198	0,13	0,153	0,213	0,216	0,16	0,157	0,154	0,148	0,047	0,069	0,015	0,029	-0,007	0,035	0,069	0,054	0,019	-0,003
	p-value	0,358	0,263	0,359	0,371	0,594	0,598	0,7	0,565	0,063	0,052	0,204	0,134	**0,037**	**0,033**	0,118	0,123	0,132	0,149	0,646	0,504	0,882	0,777	0,947	0,737	0,504	0,6	0,855	0,977
LeftMiddleFingerWS	Corr. Coef.	0,089	0,216	0,13	0,213	0,103	0,146	0,094	0,154	0,149	0,148	0,083	0,14	0,199	0,206	0,084	0,122	0,082	0,08	0,103	0,169	0,095	0,016	-0,022	0,072	0,169	0,152	0,023	-0,024
	p-value	0,386	**0,034**	0,206	**0,036**	0,318	0,154	0,36	0,131	0,144	0,149	0,416	0,17	0,051	**0,043**	0,416	0,235	0,425	0,438	0,314	0,099	0,355	0,876	0,83	0,485	0,099	0,137	0,822	0,812
RightRingFingerWS	Corr. Coef.	0,141	0,134	0,124	0,119	0,091	0,135	0,091	0,137	0,128	0,137	0,14	0,159	0,122	0,119	0,106	0,109	0,09	0,082	0,081	0,096	0,092	0,085	0,074	0,052	0,096	0,116	0,091	0,067
	p-value	0,169	0,192	0,226	0,247	0,377	0,187	0,377	0,182	0,212	0,18	0,17	0,12	0,232	0,247	0,303	0,287	0,382	0,422	0,428	0,349	0,368	0,408	0,472	0,613	0,349	0,256	0,377	0,517
LeftRingFingerWS	Corr. Coef.	0,161	0,277	0,186	0,261	0,157	0,203	0,149	0,208	0,161	0,154	0,114	0,175	0,195	0,204	0,083	0,115	0,101	0,097	0,152	0,227	0,172	0,08	0,028	0,095	0,227	0,222	0,096	0,028
	p-value	0,116	**0,006**	0,069	**0,01**	0,125	**0,046**	0,145	**0,041**	0,114	0,132	0,268	0,086	0,056	**0,045**	0,421	0,263	0,325	0,346	0,138	**0,025**	0,092	0,437	0,784	0,355	**0,025**	**0,029**	0,349	0,788
RightPinkieWS	Corr. Coef.	-0,118	-0,11	-0,113	-0,115	-0,065	-0,089	-0,056	-0,08	-0,019	0,003	-0,059	-0,044	0,003	-0,001	0,026	0,015	-0,023	-0,028	-0,104	-0,117	-0,106	-0,115	-0,112	-0,082	-0,117	-0,085	-0,111	-0,114
	p-value	0,252	0,285	0,269	0,263	0,526	0,387	0,585	0,437	0,853	0,979	0,566	0,668	0,975	0,988	0,804	0,881	0,822	0,786	0,312	0,253	0,301	0,262	0,276	0,424	0,253	0,405	0,28	0,265
LeftPinkieWS	Corr. Coef.	-0,397	-0,364	-0,337	-0,347	-0,331	-0,338	-0,309	-0,331	-0,357	-0,348	-0,355	-0,351	-0,271	-0,271	-0,331	-0,331	-0,316	-0,318	-0,39	-0,374	-0,36	-0,371	-0,341	-0,324	-0,374	-0,378	-0,365	-0,335
	p-value	**0**	**0**	**0,001**	**0,001**	**0,001**	**0,001**	**0,002**	**0,001**	**0**	**0**	**0**	**0**	**0,007**	**0,007**	**0,001**	**0,001**	**0,002**	**0,002**	**0**	**0**	**0**	**0**	**0,001**	**0,001**	**0**	**0**	**0**	**0,001**
RightPalmWS	Corr. Coef.	0,234	0,25	0,225	0,242	0,179	0,201	0,177	0,203	0,228	0,233	0,198	0,224	0,246	0,246	0,202	0,202	0,24	0,24	0,164	0,165	0,136	0,106	0,102	0,141	0,165	0,157	0,119	0,099
	p-value	**0,021**	**0,014**	**0,027**	**0,017**	0,08	**0,048**	0,082	**0,046**	**0,025**	**0,022**	0,052	**0,027**	**0,015**	**0,015**	**0,048**	**0,048**	**0,018**	**0,018**	0,109	0,106	0,186	0,301	0,322	0,169	0,106	0,124	0,247	0,336
LeftPalmWS	Corr. Coef.	-0,06	-0,022	-0,069	-0,042	-0,063	-0,093	-0,055	-0,085	0,011	0,024	-0,039	-0,001	0,011	0,017	-0,013	-0,003	-0,043	-0,054	-0,065	-0,082	-0,101	-0,11	-0,157	-0,111	-0,082	-0,069	-0,12	-0,161
	p-value	0,559	0,829	0,502	0,681	0,54	0,367	0,594	0,406	0,913	0,815	0,707	0,992	0,913	0,866	0,897	0,974	0,679	0,6	0,53	0,425	0,325	0,282	0,125	0,278	0,425	0,505	0,241	0,115
RightBottomofThumbWS	Corr. Coef.	0,054	0,091	0,044	0,095	0,082	0,111	0,105	0,105	-0,144	-0,146	-0,042	-0,074	0,003	-0,005	-0,007	-0,014	0,034	0,021	0,062	0,008	0,047	0,011	0,085	0,084	0,008	0,014	0,043	0,084
	p-value	0,603	0,374	0,668	0,357	0,424	0,281	0,306	0,305	0,161	0,152	0,686	0,473	0,979	0,962	0,946	0,895	0,743	0,841	0,55	0,935	0,647	0,915	0,41	0,415	0,935	0,893	0,674	0,415
LeftBottomofThumbWS	Corr. Coef.	-0,014	0,025	-0,016	0,014	-0,004	-0,01	0,018	-0,009	-0,119	-0,114	-0,03	-0,022	0,029	0,031	-0,016	-0,014	-0,013	-0,034	-0,015	-0,032	-0,034	-0,055	-0,035	-0,034	-0,032	-0,028	-0,046	-0,039
	p-value	0,895	0,804	0,878	0,888	0,972	0,922	0,865	0,934	0,247	0,265	0,77	0,828	0,779	0,765	0,877	0,894	0,899	0,741	0,883	0,756	0,741	0,595	0,731	0,738	0,756	0,784	0,653	0,704
TOTALBODYWS	Corr. Coef.	-0,005	0,038	0,029	0,047	-0,002	0,034	0,013	0,043	-0,003	0	0,016	0,031	0,031	0,034	0,02	0,015	0,004	-0,006	0,021	0,023	0,022	-0,019	0,024	0,022	0,023	0,034	-0,004	0,019
	p-value	0,961	0,708	0,781	0,644	0,982	0,737	0,903	0,676	0,979	0,997	0,875	0,766	0,76	0,744	0,847	0,887	0,968	0,957	0,84	0,824	0,832	0,852	0,813	0,829	0,824	0,743	0,972	0,85

* Green colored cells indicate significant positive correlation while orange colored cells indicate significant negative correlation

Figure E.17. Plucked strings instruments players' hand dimension correlations after Ratio Scaling

Weigthed Scores	Cell Contents	RightHS	LeftHS	Right2HS	Left2HS	RightHBreadth	RightHLength	LeftHBreadth	LeftHLength	RThumbTotal	LThumbTotal	RIndexFTotal	LIndexFTotal	RMiddleFTotal	LMiddleFTotal	RRingFTotal	LRingFTotal	RPinkieTotal	LPinkieTotal	RThumbWidth	RIndexFWidth	RMiddleFWidth	RRingFWidth	RPinkieWidth	LThumbWidth	LIndexFWidth	LMiddleFWidth	LRingFWidth	LPinkieWidth
NeckWS	Corr. Coef.	0,057	0,047	0,072	0,109	0,076	0,081	0,064	0,082	0,069	0,064	0,055	0,06	0,064	0,058	0,052	0,041	0,115	0,117	0,048	0,042	0,004	0,054	0,059	0,087	0,042	0,033	0,035	0,065
	p-value	0,65	0,709	0,567	0,385	0,542	0,519	0,609	0,514	0,58	0,61	0,662	0,635	0,609	0,646	0,681	0,741	0,357	0,351	0,699	0,735	0,976	0,669	0,637	0,488	0,735	0,792	0,779	0,602
RightShoulderWS	Corr. Coef.	0,228	0,154	0,245	0,207	0,236	0,145	0,221	0,136	0,266	0,26	0,212	0,22	0,222	0,211	0,242	0,233	0,175	0,176	0,17	0,234	0,198	0,295	0,258	0,188	0,234	0,188	0,219	0,278
	p-value	0,066	0,216	**0,047**	0,096	0,056	0,245	0,075	0,276	**0,031**	**0,035**	0,087	0,076	0,074	0,089	0,051	0,06	0,159	0,159	0,171	0,059	0,11	**0,016**	**0,036**	0,13	0,059	0,13	0,077	**0,024**
LeftShoulderWS	Corr. Coef.	0,108	0,084	0,102	0,079	0,18	0,128	0,175	0,118	0,128	0,127	0,133	0,135	0,033	0,033	0,115	0,112	0,145	0,131	0,212	0,178	0,195	0,224	0,241	0,254	0,178	0,189	0,216	0,229
	p-value	0,386	0,504	0,416	0,527	0,147	0,306	0,159	0,344	0,307	0,308	0,286	0,281	0,79	0,794	0,357	0,37	0,246	0,293	0,088	0,154	0,116	0,071	0,051	**0,039**	0,154	0,128	0,082	0,064
UpperBackWS	Corr. Coef.	-0,058	-0,04	-0,057	0,004	-0,032	-0,042	-0,04	-0,036	-0,049	-0,052	-0,075	-0,083	-0,001	0,002	-0,058	-0,077	-0,13	-0,106	-0,129	-0,107	-0,11	-0,073	-0,047	-0,099	-0,107	-0,1	-0,086	-0,056
	p-value	0,641	0,752	0,65	0,976	0,798	0,735	0,747	0,773	0,698	0,68	0,549	0,506	0,991	0,987	0,642	0,537	0,299	0,398	0,304	0,392	0,38	0,558	0,709	0,431	0,392	0,426	0,49	0,655
LowerBackWS	Corr. Coef.	0,083	0,019	0,093	0,131	0,108	0,064	0,11	0,04	-0,025	-0,041	-0,04	-0,025	-0,064	-0,074	-0,042	-0,055	0,039	0,054	0,156	0,058	0,105	0,105	0,17	0,166	0,058	0,073	0,128	0,158
	p-value	0,51	0,88	0,46	0,294	0,389	0,612	0,381	0,749	0,844	0,741	0,748	0,844	0,61	0,556	0,739	0,66	0,754	0,667	0,21	0,645	0,399	0,399	0,172	0,182	0,645	0,559	0,306	0,206
RightThumbWS	Corr. Coef.	0,141	0,068	0,175	0,185	0,18	0,125	0,163	0,101	0,027	0,015	0,029	0,026	0,009	-0,013	0,036	0,018	0,094	0,114	0,21	0,123	0,187	0,182	0,227	0,221	0,123	0,121	0,188	0,215
	p-value	0,258	0,589	0,16	0,137	0,148	0,318	0,19	0,42	0,832	0,902	0,815	0,833	0,94	0,916	0,775	0,888	0,452	0,361	0,091	0,323	0,132	0,145	0,066	0,074	0,323	0,334	0,131	0,083
LeftThumbWS	Corr. Coef.	0,13	0,119	0,081	0,127	0,183	0,118	0,188	0,107	0,029	0,021	-0,023	-0,006	-0,015	-0,026	-0,016	-0,033	0,061	0,078	0,188	0,106	0,156	0,137	0,211	0,195	0,106	0,143	0,155	0,196
	p-value	0,297	0,342	0,516	0,311	0,142	0,346	0,13	0,393	0,815	0,865	0,853	0,962	0,904	0,838	0,9	0,794	0,627	0,536	0,13	0,399	0,21	0,274	0,089	0,116	0,399	0,251	0,215	0,115
RightIndexFingerWS	Corr. Coef.	-0,246	-0,17	-0,334	-0,295	-0,174	-0,156	-0,166	-0,143	-0,313	-0,313	-0,262	-0,287	-0,349	-0,343	-0,327	-0,318	-0,256	-0,256	-0,126	-0,285	-0,189	-0,251	-0,125	-0,081	-0,285	-0,201	-0,198	-0,132
	p-value	**0,046**	0,173	**0,006**	**0,016**	0,163	0,211	0,183	0,253	**0,011**	**0,011**	**0,034**	**0,02**	**0,004**	**0,005**	**0,007**	**0,009**	**0,038**	**0,038**	0,314	**0,02**	0,129	**0,042**	0,318	0,518	**0,02**	0,106	0,111	0,29
LeftIndexFingerWS	Corr. Coef.	0,168	0,17	0,128	0,181	0,164	0,114	0,179	0,098	0,05	0,039	0,016	0,027	-0,044	-0,064	-0,005	-0,018	0,142	0,158	0,16	0,108	0,138	0,131	0,164	0,153	0,108	0,113	0,155	0,186
	p-value	0,177	0,173	0,307	0,147	0,19	0,364	0,15	0,433	0,689	0,758	0,901	0,827	0,723	0,612	0,969	0,886	0,254	0,206	0,199	0,388	0,268	0,296	0,188	0,22	0,388	0,367	0,213	0,134
RightMiddleFingerWS	Corr. Coef.	0,214	0,276	0,094	0,083	0,276	0,216	0,28	0,216	0,198	0,204	0,225	0,234	0,078	0,082	0,173	0,194	0,163	0,144	0,301	0,23	0,288	0,241	0,265	0,297	0,23	0,311	0,262	0,249
	p-value	0,085	**0,025**	0,455	0,51	**0,025**	0,082	**0,023**	0,081	0,111	0,1	0,069	0,059	0,535	0,513	0,165	0,118	0,192	0,249	**0,014**	0,063	**0,019**	0,052	**0,032**	**0,015**	0,063	**0,011**	**0,034**	**0,043**
LeftMiddleFingerWS	Corr. Coef.	0,091	0,08	0,074	0,112	0,149	0,112	0,147	0,099	-0,024	-0,035	0,004	-0,006	-0,119	-0,137	-0,056	-0,068	-0,001	0,015	0,171	0,096	0,167	0,162	0,236	0,182	0,096	0,134	0,19	0,216
	p-value	0,465	0,521	0,556	0,369	0,232	0,371	0,237	0,43	0,851	0,777	0,974	0,959	0,342	0,273	0,654	0,59	0,994	0,908	0,17	0,443	0,181	0,193	0,056	0,144	0,443	0,284	0,127	0,082
RightRingFingerWS	Corr. Coef.	-0,199	-0,131	-0,24	-0,209	-0,174	-0,144	-0,169	-0,133	-0,223	-0,223	-0,198	-0,206	-0,204	-0,201	-0,22	-0,214	-0,195	-0,189	-0,154	-0,227	-0,187	-0,211	-0,153	-0,126	-0,227	-0,194	-0,197	-0,161
	p-value	0,108	0,293	0,052	0,092	0,161	0,249	0,175	0,288	0,073	0,073	0,111	0,097	0,101	0,106	0,076	0,085	0,117	0,128	0,218	0,067	0,134	0,09	0,22	0,314	0,067	0,119	0,113	0,197
LeftRingFingerWS	Corr. Coef.	0,034	0,025	0,087	0,125	0,051	0,044	0,05	0,036	-0,003	-0,015	0,005	0,003	-0,024	-0,04	-0,022	-0,034	-0,016	0,004	0,063	0,043	0,056	0,094	0,125	0,071	0,043	0,032	0,082	0,105
	p-value	0,788	0,844	0,487	0,318	0,686	0,728	0,69	0,773	0,984	0,902	0,968	0,98	0,846	0,748	0,863	0,785	0,897	0,973	0,615	0,73	0,652	0,454	0,319	0,571	0,73	0,8	0,514	0,4
RightPinkieWS	Corr. Coef.	-0,195	-0,18	-0,157	-0,153	-0,197	-0,161	-0,195	-0,16	-0,189	-0,191	-0,141	-0,147	-0,152	-0,154	-0,158	-0,17	-0,235	-0,233	-0,153	-0,199	-0,165	-0,163	-0,128	-0,148	-0,199	-0,181	-0,158	-0,145
	p-value	0,117	0,148	0,208	0,221	0,112	0,198	0,117	0,199	0,129	0,124	0,258	0,238	0,223	0,217	0,206	0,173	0,057	0,06	0,22	0,109	0,184	0,191	0,306	0,236	0,109	0,146	0,206	0,244
LeftPinkieWS	Corr. Coef.	0,033	-0,002	0,04	0,071	0,095	0,058	0,089	0,046	-0,069	-0,084	-0,039	-0,05	-0,144	-0,163	-0,088	-0,107	-0,044	-0,032	0,119	0,046	0,12	0,13	0,215	0,14	0,046	0,082	0,155	0,196
	p-value	0,791	0,987	0,748	0,569	0,448	0,641	0,477	0,715	0,584	0,504	0,759	0,69	0,25	0,19	0,485	0,392	0,724	0,796	0,341	0,713	0,336	0,299	0,084	0,261	0,713	0,515	0,213	0,114
RightPalmWS	Corr. Coef.	-0,083	-0,073	-0,064	-0,055	-0,07	-0,022	-0,071	-0,025	-0,109	-0,103	-0,035	-0,063	-0,1	-0,103	-0,077	-0,083	-0,119	-0,114	-0,044	-0,083	-0,029	-0,046	-0,015	-0,026	-0,083	-0,068	-0,037	-0,026
	p-value	0,509	0,562	0,611	0,658	0,578	0,864	0,573	0,841	0,381	0,412	0,781	0,613	0,425	0,412	0,538	0,51	0,34	0,363	0,726	0,506	0,816	0,711	0,906	0,833	0,506	0,588	0,77	0,833
LeftPalmWS	Corr. Coef.	-0,274	-0,2	-0,302	-0,262	-0,233	-0,188	-0,229	-0,173	-0,282	-0,267	-0,226	-0,245	-0,255	-0,245	-0,256	-0,267	-0,286	-0,284	-0,222	-0,29	-0,235	-0,267	-0,214	-0,193	-0,29	-0,224	-0,243	-0,23
	p-value	**0,026**	0,107	**0,014**	**0,034**	0,059	0,13	0,065	0,164	**0,022**	**0,03**	0,068	**0,048**	**0,039**	**0,048**	**0,038**	**0,03**	**0,02**	**0,021**	0,074	**0,018**	0,057	**0,03**	0,085	0,121	**0,018**	0,07	**0,05**	0,063
RightBottomofThumbWS	Corr. Coef.	0,319	0,334	0,267	0,256	0,276	0,292	0,284	0,286	0,298	0,306	0,312	0,312	0,222	0,227	0,285	0,293	0,279	0,278	0,255	0,258	0,259	0,252	0,21	0,244	0,258	0,247	0,241	0,242
	p-value	**0,009**	**0,006**	**0,03**	**0,038**	**0,025**	**0,017**	**0,021**	**0,02**	**0,015**	**0,012**	**0,011**	**0,011**	0,073	0,066	**0,021**	**0,017**	**0,023**	**0,024**	**0,039**	**0,037**	**0,036**	**0,041**	0,09	**0,049**	**0,037**	**0,046**	0,052	0,051
LeftBottomofThumbWS	Corr. Coef.	0,163	0,066	0,198	0,153	0,16	0,094	0,146	0,055	0,068	0,059	0,067	0,061	0,034	0,024	0,078	0,076	0,068	0,08	0,217	0,173	0,212	0,216	0,227	0,198	0,173	0,148	0,187	0,219
	p-value	0,191	0,596	0,11	0,22	0,199	0,455	0,242	0,661	0,586	0,636	0,592	0,625	0,787	0,85	0,534	0,542	0,588	0,525	0,081	0,164	0,087	0,081	0,067	0,111	0,164	0,235	0,133	0,077
TOTALBODYWS	Corr. Coef.	0,009	-0,065	0,058	0,029	0,113	-0,015	0,088	-0,038	-0,003	-0,011	-0,039	-0,043	-0,045	-0,057	-0,011	-0,027	-0,029	-0,018	0,131	0,03	0,081	0,119	0,191	0,198	0,03	0,034	0,09	0,179
	p-value	0,944	0,606	0,641	0,816	0,366	0,905	0,482	0,765	0,98	0,928	0,757	0,73	0,718	0,652	0,931	0,831	0,819	0,888	0,293	0,811	0,52	0,342	0,125	0,111	0,811	0,789	0,474	0,15

* Green colored cells indicate significant positive correlation while orange colored cells indicate significant negative correlation

Figure E.18. Strings instruments players' hand dimension correlations after Ratio Scaling

Weigthed Scores	Cell Contents	RightHS	LeftHS	Right2HS	Left2HS	RightHBreadth	RightHLength	LeftHBreadth	LeftHLength	RThumbTotal	LThumbTotal	RIndexFTotal	LIndexFTotal	RMiddleFTotal	LMiddleFTotal	RRingFTotal	LRingFTotal	RPinkieTotal	LPinkieTotal	RThumbWidth	RIndexFWidth	RMiddleFWidth	RRingFWidth	RPinkieWidth	LThumbWidth	LIndexFWidth	LMiddleFWidth	LRingFWidth	LPinkieWidth
NeckWS	Corr. Coef.	-0,114	-0,179	-0,017	-0,058	-0,119	-0,128	-0,132	-0,135	-0,104	-0,112	-0,089	-0,106	-0,061	-0,074	-0,071	-0,097	-0,091	-0,089	-0,123	-0,065	-0,092	-0,034	-0,052	-0,122	-0,065	-0,116	-0,066	-0,05
	p-value	0,385	0,171	0,899	0,66	0,366	0,331	0,313	0,303	0,428	0,395	0,497	0,418	0,643	0,573	0,592	0,459	0,488	0,497	0,35	0,624	0,485	0,795	0,69	0,353	0,624	0,376	0,615	0,704
RightShoulderWS	Corr. Coef.	0,074	-0,075	0,156	0,121	0,036	0,074	0,022	0,052	0,085	0,065	0,129	0,11	0,115	0,111	0,134	0,115	0,025	0,023	0,054	0,111	0,093	0,157	0,131	0,046	0,111	0,04	0,134	0,133
	p-value	0,575	0,567	0,235	0,359	0,784	0,574	0,865	0,694	0,521	0,623	0,325	0,402	0,382	0,4	0,306	0,38	0,847	0,862	0,682	0,399	0,482	0,23	0,319	0,727	0,399	0,762	0,307	0,311
LeftShoulderWS	Corr. Coef.	0,16	0,104	0,126	0,138	0,164	0,141	0,174	0,127	0,121	0,104	0,119	0,122	0,065	0,055	0,106	0,103	0,085	0,075	0,221	0,173	0,199	0,148	0,189	0,208	0,173	0,182	0,174	0,192
	p-value	0,223	0,428	0,338	0,293	0,21	0,281	0,183	0,333	0,356	0,428	0,367	0,355	0,621	0,676	0,421	0,434	0,516	0,568	0,09	0,185	0,127	0,258	0,148	0,11	0,185	0,165	0,183	0,142
UpperBackWS	Corr. Coef.	0,053	-0,015	0,073	0,053	0,066	0,085	0,058	0,067	0,062	0,063	0,108	0,082	0,049	0,053	0,091	0,083	0,104	0,106	0,051	0,053	0,07	0,11	0,09	0,082	0,053	0,051	0,098	0,092
	p-value	0,687	0,911	0,581	0,686	0,616	0,52	0,658	0,608	0,635	0,634	0,413	0,531	0,708	0,686	0,488	0,527	0,428	0,419	0,698	0,688	0,595	0,402	0,496	0,533	0,688	0,698	0,456	0,487
LowerBackWS	Corr. Coef.	-0,034	0,137	-0,182	-0,136	-0,002	-0,03	0,001	-0,008	-0,011	0,003	-0,084	-0,059	-0,072	-0,085	-0,095	-0,066	-0,052	-0,068	-0,038	-0,033	-0,051	-0,115	-0,122	-0,077	-0,033	0,022	-0,1	-0,123
	p-value	0,799	0,295	0,165	0,299	0,986	0,822	0,991	0,952	0,935	0,984	0,523	0,657	0,582	0,519	0,469	0,618	0,694	0,607	0,771	0,804	0,698	0,382	0,352	0,558	0,804	0,868	0,449	0,349
RightThumbWS	Corr. Coef.	0,185	0,113	0,258	0,253	0,133	0,134	0,127	0,115	0,173	0,154	0,172	0,177	0,167	0,16	0,175	0,167	0,108	0,103	0,156	0,222	0,195	0,197	0,171	0,127	0,222	0,174	0,193	0,171
	p-value	0,158	0,39	**0,046**	0,051	0,311	0,308	0,333	0,383	0,186	0,242	0,19	0,177	0,202	0,221	0,181	0,202	0,41	0,435	0,232	0,089	0,136	0,131	0,192	0,333	0,089	0,183	0,14	0,192
LeftThumbWS	Corr. Coef.	0,038	-0,069	0,177	0,134	-0,015	0	-0,025	-0,024	0,059	0,036	0,073	0,074	0,077	0,07	0,08	0,062	-0,037	-0,035	0,012	0,109	0,064	0,106	0,066	-0,007	0,109	0,03	0,083	0,067
	p-value	0,774	0,602	0,176	0,308	0,912	1	0,85	0,853	0,653	0,787	0,579	0,573	0,556	0,593	0,545	0,635	0,78	0,792	0,926	0,409	0,625	0,419	0,617	0,955	0,409	0,82	0,529	0,612
RightIndexFingerWS	Corr. Coef.	-0,082	-0,035	0,009	0,006	-0,155	-0,096	-0,177	-0,091	0,075	0,082	0,038	0,06	0,16	0,159	0,06	0,075	-0,078	-0,08	-0,243	-0,039	-0,165	-0,09	-0,23	-0,284	-0,039	-0,116	-0,154	-0,23
	p-value	0,534	0,788	0,948	0,966	0,236	0,466	0,176	0,487	0,567	0,533	0,771	0,646	0,221	0,225	0,649	0,567	0,554	0,542	0,062	0,769	0,208	0,495	0,076	**0,028**	0,769	0,377	0,24	0,076
LeftIndexFingerWS	Corr. Coef.	-0,098	-0,065	-0,058	-0,056	-0,133	-0,116	-0,139	-0,118	-0,041	-0,039	-0,064	-0,04	-0,035	-0,033	-0,076	-0,053	-0,134	-0,135	-0,141	-0,064	-0,119	-0,105	-0,148	-0,159	-0,064	-0,092	-0,118	-0,148
	p-value	0,455	0,624	0,661	0,669	0,31	0,378	0,289	0,369	0,753	0,765	0,629	0,762	0,79	0,8	0,564	0,688	0,306	0,304	0,283	0,629	0,366	0,425	0,258	0,224	0,629	0,483	0,368	0,258
RightMiddleFingerWS	Corr. Coef.	0,093	0,148	0,096	0,125	0,051	0,055	0,032	0,058	0,183	0,183	0,119	0,157	0,202	0,193	0,141	0,151	0,074	0,071	-0,016	0,103	0,022	0,019	-0,067	-0,083	0,103	0,087	0	-0,067
	p-value	0,479	0,26	0,464	0,341	0,697	0,679	0,808	0,661	0,162	0,162	0,366	0,23	0,121	0,141	0,282	0,25	0,575	0,592	0,903	0,435	0,865	0,884	0,609	0,526	0,435	0,51	1	0,609
LeftMiddleFingerWS	Corr. Coef.	0,082	0,145	0,096	0,124	0,051	0,023	0,04	0,023	0,141	0,138	0,064	0,113	0,127	0,117	0,082	0,092	0,033	0,03	0,04	0,113	0,047	0,012	-0,033	-0,016	0,113	0,099	0,012	-0,033
	p-value	0,534	0,271	0,467	0,347	0,702	0,864	0,761	0,864	0,282	0,295	0,625	0,389	0,333	0,375	0,534	0,483	0,802	0,822	0,761	0,389	0,721	0,926	0,802	0,905	0,389	0,45	0,926	0,802
RightRingFingerWS	Corr. Coef.	0,075	0,056	0,133	0,137	0,02	0,003	-0,007	-0,004	0,134	0,127	0,072	0,112	0,153	0,141	0,106	0,105	0,044	0,041	-0,012	0,111	0,024	0,055	-0,027	-0,081	0,111	0,061	0,031	-0,027
	p-value	0,567	0,672	0,309	0,295	0,877	0,983	0,959	0,975	0,308	0,334	0,585	0,394	0,243	0,282	0,421	0,425	0,737	0,755	0,93	0,398	0,854	0,676	0,838	0,54	0,398	0,645	0,812	0,838
LeftRingFingerWS	Corr. Coef.	0,191	0,258	0,154	0,188	0,16	0,127	0,152	0,127	0,191	0,183	0,127	0,17	0,125	0,122	0,121	0,133	0,12	0,116	0,157	0,21	0,163	0,117	0,074	0,095	0,21	0,214	0,12	0,074
	p-value	0,144	**0,047**	0,24	0,149	0,222	0,332	0,246	0,332	0,144	0,161	0,332	0,193	0,34	0,355	0,357	0,313	0,359	0,375	0,232	0,107	0,213	0,374	0,576	0,472	0,107	0,101	0,36	0,576
RightPinkieWS	Corr. Coef.	-0,245	-0,201	-0,181	-0,196	-0,266	-0,22	-0,277	-0,213	-0,17	-0,162	-0,159	-0,17	-0,099	-0,1	-0,16	-0,163	-0,248	-0,249	-0,305	-0,215	-0,277	-0,206	-0,262	-0,302	-0,215	-0,261	-0,245	-0,264
	p-value	0,06	0,123	0,167	0,133	**0,04**	0,091	**0,032**	0,102	0,194	0,217	0,226	0,195	0,45	0,448	0,223	0,213	0,056	0,055	**0,018**	0,099	**0,032**	0,114	**0,043**	**0,019**	0,099	**0,044**	0,059	**0,042**
LeftPinkieWS	Corr. Coef.	0,05	0,139	-0,009	0,017	0,051	0,03	0,059	0,036	0,024	0,022	-0,012	0,009	-0,025	-0,028	-0,024	-0,015	-0,018	-0,021	0,057	0,06	0,052	-0,002	0,006	0,023	0,06	0,079	0,016	0,004
	p-value	0,703	0,291	0,946	0,899	0,698	0,819	0,654	0,783	0,857	0,869	0,93	0,945	0,848	0,831	0,857	0,908	0,891	0,871	0,663	0,651	0,695	0,988	0,963	0,862	0,651	0,548	0,902	0,978
RightPalmWS	Corr. Coef.	-0,031	0,038	0,043	0,055	-0,093	-0,121	-0,101	-0,115	0,076	0,079	-0,014	0,029	0,115	0,111	0,04	0,038	-0,018	-0,022	-0,103	-0,003	-0,101	-0,096	-0,187	-0,15	-0,003	-0,057	-0,137	-0,187
	p-value	0,812	0,772	0,747	0,679	0,478	0,356	0,444	0,382	0,566	0,55	0,912	0,825	0,382	0,397	0,76	0,776	0,894	0,87	0,435	0,981	0,444	0,464	0,154	0,253	0,981	0,667	0,296	0,154
LeftPalmWS	Corr. Coef.	-0,272	-0,186	-0,188	-0,192	-0,312	-0,275	-0,326	-0,263	-0,14	-0,13	-0,171	-0,162	-0,053	-0,049	-0,143	-0,14	-0,231	-0,232	-0,366	-0,245	-0,341	-0,282	-0,368	-0,376	-0,245	-0,297	-0,331	-0,368
	p-value	**0,036**	0,154	0,15	0,142	**0,015**	**0,033**	**0,011**	**0,042**	0,286	0,322	0,192	0,215	0,69	0,708	0,276	0,288	0,076	0,075	**0,004**	0,059	**0,008**	**0,029**	**0,004**	**0,003**	0,059	**0,021**	**0,01**	**0,004**
RightBottomofThumbWS	Corr. Coef.	0,075	0,201	0,043	0,096	0,03	0,036	0,032	0,052	0,167	0,18	0,091	0,128	0,171	0,165	0,088	0,117	0,035	0,023	-0,022	0,08	-0,002	-0,046	-0,109	-0,07	0,08	0,079	-0,055	-0,111
	p-value	0,567	0,124	0,747	0,464	0,821	0,785	0,808	0,693	0,203	0,169	0,49	0,33	0,19	0,207	0,503	0,374	0,79	0,861	0,867	0,545	0,988	0,729	0,408	0,597	0,545	0,551	0,676	0,4
LeftBottomofThumbWS	Corr. Coef.	0,121	0,246	0,042	0,102	0,088	0,103	0,084	0,118	0,177	0,189	0,113	0,144	0,151	0,145	0,092	0,126	0,093	0,083	0,006	0,107	0,039	-0,006	-0,069	-0,051	0,107	0,133	-0,007	-0,071
	p-value	0,355	0,058	0,753	0,436	0,504	0,435	0,523	0,37	0,175	0,147	0,39	0,272	0,248	0,268	0,487	0,337	0,48	0,53	0,962	0,417	0,77	0,963	0,6	0,7	0,417	0,313	0,956	0,59
TOTALBODYWS	Corr. Coef.	-0,113	-0,142	-0,056	-0,085	-0,126	-0,105	-0,15	-0,106	-0,025	-0,025	-0,017	-0,032	0,024	0,014	-0,011	-0,024	-0,124	-0,131	-0,172	-0,055	-0,117	-0,046	-0,109	-0,191	-0,055	-0,109	-0,084	-0,108
	p-value	0,389	0,279	0,67	0,519	0,336	0,423	0,253	0,421	0,85	0,847	0,895	0,806	0,857	0,918	0,935	0,858	0,344	0,32	0,19	0,679	0,374	0,726	0,406	0,144	0,679	0,407	0,525	0,411

* Green colored cells indicate significant positive correlation while orange colored cells indicate significant negative correlation

Figure E.19. Woodwind instruments players' hand dimension correlations after Ratio Scaling

Table E.1. The dimensions used from Turkish male population (Ekşioğlu, 2015)

Measurement	**Age Group**				
	18-29 years Mean(SD)	**30-39 years Mean(SD)**	**40-49 years Mean(SD)**	**50-59 years Mean(SD)**	**60-70 years Mean(SD)**
Stature (Normal)	176.2 (7.0)	174.3 (6.6)	171.0 (7.3)	168.1 (6.7)	165.0 (7.1)
Hand length	18.9 (0.9)	18.9 (1.2)	18.9 (1.4)	18.6 (1.3)	18.5 (1.0)
Hand breadth	8.7 (0.7)	8.9 (0.5)	8.8 (0.5)	8.9 (0.5)	8.9 (0.5)
Index finger length	7.3 (0.5)	7.3 (0.5)	7.3 (0.6)	7.3 (0.5)	7.2 (0.6)

Table E.2. The dimensions used from Turkish female population (Ekşioğlu, 2015)

Measurement	**Age Group**				
	18-29 years Mean(SD)	**30-39 years Mean(SD)**	**40-49 years Mean(SD)**	**50-59 years Mean(SD)**	**60-70 years Mean(SD)**
Stature (Normal)	160.26 (6.70)	158.15(4.99)	154.43(6.07)	156.26(6.03)	153.32(6.63)
Hand length	17.19 (1.20)	17.29 (0.81)	17.07 (0.84)	17.30 (0.99)	16.94 (0.93)
Hand breadth	7.72 (0.46)	7.90 (0.48)	8.00 (0.43)	8.20 (0.48)	8.13 (0.45)
Index finger length	7.12 (0.55)	6.94 (0.47)	6.97 (0.54)	7.06 (0.51)	6.74 (0.41)