2013

Documenting postural changes and repetition among violin players and their influence in the development of musculoskeletal disorders

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DOCUMENTING POSTURAL CHANGES AND REPETITION AMONG VIOLIN PLAYERS AND THEIR INFLUENCE IN THE DEVELOPMENT OF MUSCULOSKELETAL DISORDERS

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
In partial fulfillment of the
requirements for the degree of
Master of Science

in

Industrial Engineering

by
Cristina Handal
B.S., Louisiana State University. 2010
May 2013

ACKNOWLEDGMENTS

First and foremost I would like to thank God, the creator and sustainer of everything. He has been my support throughout my entire life.

I would like to express my sincere gratitude to my advisor Dr. Laura Ikuma who has helped me in every step of this lengthy process. Thank you for encouraging me to always do my best. Thank you as well to the other committee members, Dr. Aghazadeh and Dr. Nahmens.

Thanks to the participants for their help and to my fellow colleagues: Negar, Saif, Heath, Drew, Sid, Manouj and Ram for their moral support in needed times. Special thanks to my dear friend Rachel Hecksel who has believed in me and supported me through rough times.

I would also like to thank my beloved family: my siblings Iris, Flor and Abraham for their support even at a distance, for their prayers and their consistent encouragement and to my amazing parents, Iris Varela and Carlos Handal. No words can come close to express my gratitude and love to them; they have been an exceptional example to me of hard work and perseverance. I hope to have made them proud.

Finally, I dedicate this thesis to the One who made it possible, my Lord and Savior. Through the highs and lows in life, He has guided me all the way, every day. To Him be the glory for all eternity.

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ABSTRACT

This study focused on documenting changes in posture and the number of wrist and forearm repetitions among violin/viola players during an experiment session to attempt to understand the development of musculoskeletal disorders. Also, the perception of discomfort and pain felt by the violin/viola players in the past and the number that had been diagnosed with a disorder was documented. Finally, possible correlations were calculated between pain/discomfort with variables like the number of years playing the violin, hours of practice/day, frequency of pain, gender, and dominant hand and among different pain/discomfort variables (pain/discomfort before the experiment, after the experiment and the change in pain/discomfort throughout the experiment) and ultimately possible relationships were determined between the different variables.

This study's population was violin/viola players (students and professionals) above the age of 18. Electrogoniometers were used to measure the postural changes and the software used with the equipment provided a count of the repetitions. The independent variables accounted for pain and discomfort while the dependent variables accounted for the demographics as well as posture and repetition.

Descriptive statistics were computed for the postural changes and averages for the number of repetitions. Left Radial, Left Flexion and Left Supination displayed the most extreme postural changes, while the right hand repetitions in the radial/ulnar plane had the highest number of repetitions.

Ratings for the level of pain/discomfort were averaged and a paired t-test showed a significant difference between the level of pain before and after the experiment session. Correlation analyses confirmed that extreme postures of the left hand and high number of

repetitions on the right hand are associated with a higher change in discomfort. Finally, predictors for the number of pain days in a year, the level of discomfort after the experiment and the change in discomfort included repetitions of the right hand in radial/ulnar plane and gender indicating that repetitive motions and being a female could lead to increased discomfort.

In summary, this study concluded that more extreme postural deviations, higher number of repetitions, more hours of practice per day and shorter periods of practice can lead to an increase in discomfort/pain.

CHAPTER 1

INTRODUCTION

Playing a musical instrument is one of the most complex tasks the human body can perform, placing the highest of demands on the musculoskeletal system (Steinmetz, Seidel, & Muche, 2010). Muscles, joints, and nerves very often have to function beyond their normal physiologic abilities to allow musicians to perform (Munte, Altenmuller, & Jancke, 2002). It is not unusual for a young musician commencing advanced music study at a university at age 20 to have practiced the instrument up to 10,000 hours already (Steinmetz et al., 2010). This places musicians at a high risk for development of musculoskeletal disorders, also known as playing-related musculoskeletal disorders (PRMDs).

Musicians are at high risk for developing PRMDs ranging in prevalence from approximately 30% to almost 90% (Zaza, 1998). In a sample of 672 instrumentalists evaluated in a performing arts clinic, 71% were diagnosed with having a musculoskeletal disorder (R. J. Lederman, 1994). Other studies have shown that up to 80% of professional musicians have musculoskeletal problems when playing their instrument (Fishbein, Middlestadt, Ottati, Straus, & Ellis, 1988; H. Fry, 1986; HJ Fry, 1986; R. Lederman & Calabrese, 1986). Professional musicians are not the only ones affected. Studies have shown the rates of PRMDs in music students vary between 43% and 63% (Larsson, Baum, Mudholkar, & Kollia, 1993; Roach, Martinez, & Anderson, 1994; Zaza, 1992). Roach and colleagues compared 90 university student instrumentalists (defined as individuals who had played for at least 7 hours per week during the preceding month) with a group of 159 non instrumentalists (Roach et al., 1994). Respondents were asked to report on "any areas in which they have had joint pain at least 2 days" during the previous 4-week period. In their findings, the authors reported that 67% of instrumentalists reported such pain (Roach et al., 1994). Pratt and collaborators compared a group of 246 university music students with 416 non-music majors. "Performance related pain or discomfort" was recorded as 0 ("unnoticeable") to 4 ("extreme"). Among the respondents 87% reported some pain and the prevalence of at least moderate pain was 47% (Pratt, Jessop, & Niemann, 1992). Prevalence rates differ between instrument types and are generally found to be higher among string players than in wind instrumentalists and higher in females than males (Heming, 2004).

Given that a high level of performance is typically desired by a musician, they are required to dedicate large amounts of time practicing their instruments (Heming, 2004). Musicians who want to play to a high standard will rehearse for a minimum of 3 hours a day with few (if any) breaks (Ibsen, 1986; Williamon & Valentine, 2000). These 3 or more hours may include individual practice only or individual practice combined with orchestra/chamber rehearsals or special events like wedding receptions, graduations, church services, etc.

While playing their instrument, musicians sustain static postures; thus, the postural effort is high. In addition, the size and weight of the instrument adds to postural effort, as there is often the need to provide support against gravity in an unnatural, often asymmetric position (Heming, 2004). Documenting postural changes and its effects have been researched in other fields. However, postural changes among musicians have yet to be documented in order to understand their effect and possible correlation with musculoskeletal pain/discomfort and therefore with the development of musculoskeletal disorders.

Repetition is also high in musicians given that in order to learn any musical excerpt they must repeat it until it is mastered; yet, the sole act of playing is repetitive. Despite the lack of research of repetition in musicians, the effects of repetition have been studied in other fields. Epidemiological studies have shown that workers performing activities requiring repetitive static loading periods every day reported significantly higher incidents of disability when compared with workers performing fewer such periods every day (Sbriccoli et al., 2004).

Thus, there is a need to understand how postural changes and repetition affect musicians to determine their influence in the development of musculoskeletal disorders. Therefore, documenting the postural changes and the number of repetitions among musicians is needed along with an evaluation of pain or discomfort felt by musicians and a count of the number diagnosed with a musculoskeletal disorder through professional examination. Then, possible correlations between posture and repetition with pain/discomfort can be established.

1.1 Objectives

The objectives of this study are to:

- Objective 1: Document the postural changes and number of wrist and forearm repetitions among a specific set of musicians, violin/viola players, during an experiment session.
- Objective 2: Evaluate the perception of pain or discomfort felt by experiment participants before and after a short experiment session.
- Objective 3: Document how many participants have experienced pain over a one-year period and where as well as how many have been diagnosed with a PRMD.
- Objective 4: Determine possible correlations between pain/discomfort with variables like the number of years playing the violin, hours of practice/day, frequency of pain, gender, and dominant hand, and between the different pain/discomfort variables (pain/discomfort before the experiment, after the experiment and the change in pain/discomfort throughout the experiment).
- Objective 5: Determine possible relationships between posture and repetition with pain/discomfort.

1.2 Scope

This study will analyze the effects of only two physical risk factors (posture and repetition) on the development of playing-related musculoskeletal disorders and not include other physical risk factors of force and vibration. Also, the participants recruited will only be violin/viola players who major in violin/viola performance at LSU or are music professionals all above the age 18. The reasoning behind selecting only violin/viola players is their seemingly unnatural playing posture and for consistency in posture across participants. The length of the experiment session will be 40 minutes, 10 minutes of warm-up and 30 minutes of actual practice. The intent is to replicate a practice session as closely as possible. However, musicians typically practice much more than 40 minutes and sometimes without breaks which increases the likelihood of experiencing discomfort or pain. During the experiment session, participants will be asked to warm up with standard warm-up and technique exercises, which include scale (notes in ascending or/and descending succession) playing. This is done to provide some consistency between participants. For the remaining 30 minutes, participants will be asked to play a piece or etude they have been working on. This results in every participant playing something different which could affect the level of pain/discomfort felt. Musical pieces or etudes with faster tempos or special dynamics and techniques can impose higher demands on musicians making them more susceptible to pain or discomfort.

1.3 Relevance to industry

Despite the number of studies and the amount of research that has been done on how physical risk factors influence the development of pain/discomfort and ultimately lead to the appearance of musculoskeletal disorders in many fields (construction, fishing, mining), there is a lack of research on how these physical risks factors affect musicians in their development of pain/discomfort. This study will attempt to determine if there is a possible correlation between changes in posture and number of repetitions with pain/discomfort within musicians.

CHAPTER 2

LITERATURE REVIEW

Musculoskeletal disorders are a highly prevalent occupational health problem around the globe. The World Health Organization recognizes that musculoskeletal disorders are considered work-related when the work activities and work conditions may significantly contribute to their development or exacerbation (World Health Organization, 1985). Now, the cost and burden of developing a work related musculoskeletal disorder have become enormous. In 2008, overexertion was ranked number one in the top five workplace injury causes costing businesses $13 billion in direct costs in the United States (Mutual, 2010). Along with these direct costs, indirect costs can also represent an expensive burden. These indirect costs include training and compensating replacement workers, repairing damaged property, accident investigation and implementation of corrective action, scheduling delays and lost productivity, administrative expense, low employee morale and increased absenteeism. At times, these indirect costs can amount to much more than the direct costs of an injury. In summary, occupational injuries have a major economic impact on employers and employees by imposing a long-term physical impediment (as some workers never fully recover), and a social load (as these injuries can potentially affect many areas of life like family and personal relationships, leisure activities or the pursuit of a career).

Among the different occupations that have been affected by work related musculoskeletal disorders are musicians. The musculoskeletal disorders derived from playing an instrument have taken numerous names, including “overuse syndrome”, “cumulative trauma disorder” and “repetitive strain injury” (Bragge, Bialocerkowski, & McMeeken, 2006). Authors argue against the use of the above terms because they imply a specific etiology that cannot necessarily be supported scientifically (Winspur, 2003). Instead, it has been suggested to use the term "playing related musculoskeletal disorders" (PRMDs) as it seems an appropriate music-specific derivative of work-related musculoskeletal disorder (Bragge et al., 2006).

2.1 Prevalence of Playing Related Musculoskeletal Disorders

Musicians constitute a group of people that are at a high risk of musculoskeletal disorders due to the physical and psychological stresses they endure on a daily basis as part of their profession. The prevalence of PRMDs among musicians ranges from approximately 30% to almost 90% (Zaza, 1998). This prevalence is seemingly high given that playing a musical instrument is a complex task which places high demands on the human body specifically on the musculoskeletal system.

Studies have shown that musicians are highly affected by the previously mentioned musculoskeletal disorders. In a sample of 672 instrumentalists evaluated in a performing arts clinic, 71% were diagnosed with having a musculoskeletal disorders (R. J. Lederman, 1994). In another study conducted by the Department of Neurology and Medical Center for Performing Artists at Cleveland, 64% out of 1353 instrumentalists were diagnosed with a musculoskeletal disorder (R. J. Lederman, 2003). This study also showed that the most common disorder experienced by musicians were regional muscle pain syndrome followed by nerve entrapment disorders like carpal tunnel and thoracic outlet syndrome. Bejjani et al. (1996) found a 77.5% prevalence of upper extremity disorders among violinists, violists, cellists, double bass players, pianists, harpists, and guitarists. In a study of 40 musicians, Amadio and Russotti (1990) concluded that the most common diagnosis was inflammatory tendon disorders followed by nerve entrapment syndromes. However, prevalence rates differ between instruments types and are generally found to be higher among string players than in wind instrumentalists and higher in females than males (Heming, 2004). Dunitz (2000) showed that the most common disorders among musicians include pain and overuse injuries, entrapment and peripheral neuropathies, and focal dystonias (Dunitz, 2000). In terms of incidence, two retrospective cohort studies estimated the annual incidence of upper extremity musculoskeletal disorders at 8.5 PRMD episodes per 100 university music performance majors (Zaza, 1998).

2.2 Risk Factors for Musculoskeletal Disorders

There are four physical risk factors that can affect the development of playing related musculoskeletal disorders: awkward postures, repetition, high levels of force, and vibration. Other risk factors that contribute to the development of PRMDs are psychosocial factors such as job demands, which can lead to stress or anxiety, as well as individual risk factors like age and gender. Alongside these are obesity, smoking habits, muscle strength and other aspects of work capacity (Punnett & Wegman, 2004). Thus, the development of musculoskeletal disorders and thus PRMDs is multifactorial; the environment and the way work (playing) is carried out can contribute significantly to the onset of such diseases but represent only two of the many causes (Valachi & Valachi, 2003). However, for purposes of this paper, the focus will be on two physical risk factors only: posture and repetition.

2.3 Physical Risk Factors

One of the physical risk factors in the development of musculoskeletal disorders is posture. In industry, working in static or awkward postures, i.e. postures with hands above shoulder level, or prolonged standing and sitting can influence the development of musculoskeletal disorders**.** Studies have shown that adopting certain postures such as kneeling, stooping, squatting, or lying down for significant periods of the workday, can lead to the development of musculoskeletal disorders across multiple occupations (S. Gallagher, 2005; Gerr, Marcus, & Monteilh, 2004). In a study conducted by Gallagher (2005), work in unusual and restricted postures was associated with significantly higher rates of musculoskeletal complaints compared to workers not adopting these postures. This study also concluded that workers who adopt unusual or restricted postures not only have a higher risk for developing musculoskeletal problems but also exhibit reduced strength and lifting capacity (Sean Gallagher, 2005). A cross sectional study performed by Starr et al. investigated the relationship between upper limb posture and symptoms of back and upper limb discomfort among 100 VDT (Visual Display Terminal) operators. Results from this study revealed that back discomfort was reported significantly more frequently with downward monitor viewing angle (Starr, Shute, & Thompson, 1985). Thus, awkward postures are associated with more discomfort which could lead to the development of a musculoskeletal disorder.

For musicians, research on how posture affects the development of PRMDs needs to focus on specific instruments because the physical demands (and therefore the risks) of playing different instruments are highly variable (A.G. Brandfonbrener, 1997). Early research regarding injury rates and postulated risk factors associated with PRMDs has been conducted on mixed instrumental cohorts. A common finding in these studies was that playing related disorders were more prevalent in pianists, guitarists and string players than in woodwind players (Fry, 1988; Manchester & Flieder, 1991).

In musicians, posture is influenced by the size and weight of the instrument, as there is often the need to provide support against gravity in an unnatural, often asymmetric position (Heming, 2004). In this context, it is important to realize that frequently the musical instrument becomes an extension of professional musicians (Ostwald, 1992). Musicians' postures may not be all that different from others, but the combination of deficient posture and playing an instrument may become problematic (Cailliet, 1990). For example, wind instrumentalists with forward head posture may experience difficulty with their embouchure and breathing, and may suffer from frequent headaches (Fernandez de las Penas, Cuadrado, & Pareja, 2007). Similarly, violinists with forward head posture and poor axial extension of the head may have difficulty with prolonged bowing and with positioning the fingers of the left hand in the strings, due to excessive internal rotation of the left arm. Violinists often play with their head tilted to the left and left rotation of the cervical spine, elevation of the left shoulder, and a scoliotic curve of the thoracic spine, combined with a preference to carry the weight of the body on the right foot, which in turn induces a downward shift of the left pelvis, and a scoliotic curvature of the lumbar spine (Kapandji, 2000). Figure 1 depicts an example of an improper right wrist posture; the wrist is hyper flexed which could lead to wrist discomfort.

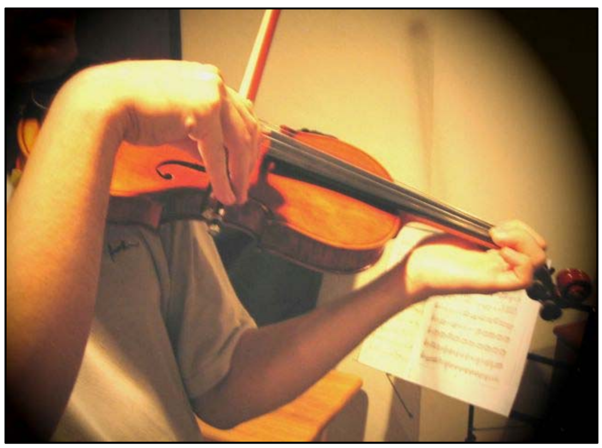

Figure 2.1: Example of an improper posture in a violin player
Source: (http://andrewfilmer.wordpress.com/bangkok-string-postings/basic-posture/)

Another major risk factor that has been associated with the development of PRMDs is force. Soft tissues, including muscle, tendon, ligament, fascia, synovia, cartilage and nerve, will fail when sufficient force is applied (National Research Council & Comittee on Human Factors, 1999). In general, activities at work, daily living and recreation may produce biomechanical forces upon the body that approach the limits of the mechanical properties of soft tissue. Ethical issues in experimental research prevent studies from being performed with *in vivo* human tissue that test the responses at these upper limits. However, cadaver studies and animal modeling have provided supportive evidence of such limits and that deformation of the tissue may lead to an inflammation response, muscle fatigue and failure at a microscopic level (National Research Council & Comittee on Human Factors, 1999). For example, typists have been a center of attention for studies centering on the effects of force and keyboard use since higher prevalence rates of musculoskeletal disorders have been reported for keyboard users compared to non-keyboard users, suggesting that keyboard use is an occupational risk factor (Bernard, Sauter, Peterson, Fine, & Hales, 1994). Different typing styles have been studied by Pascarelli and Kella (1993) who proposed that typists who hit the keys with excessive vigor creating a loud clacking noise (the ‘‘Clackers’’), had higher rates of upper limb disorders. This may suggest that higher typing force could generate greater biomechanical stresses resulting in musculoskeletal symptoms (Pascarelli & Kella, 1993). Musicians may also require applying force when playing their instrument; these mechanical stresses and static loading may be high especially on the upper limbs and smaller joints. (Cameron & McCutcheon, 1992).

The third major physical risk factor associated with the development of PRMDs is repetition. The cumulative effects of repetitive static loading of the joints over the days, weeks and years is thought of as a major risk factor for musculoskeletal disorders, even if the loads are within the physiologic range of the tissues (Sbriccoli et al., 2004). Epidemiological studies have shown that workers performing activities requiring more repetitive static loading periods every day reported with significantly higher incidents of disability when compared with workers performing fewer such periods every day (Sbriccoli et al., 2004). In musicians, repetition is high given that the sole act of playing is repetitive, and this repetition is compounded by practice sessions requiring repeating passages to mastery.

Finally, vibration can seriously injure tendons, muscles, joints and nerves. Vibration has been cited as an etiologic factor of chronic nerve and tendon disorders, including carpal tunnel syndrome and tendonitis (Cannon, Bernacki, & Walter, 1981). The evidence of the contribution of vibration for the development of musculoskeletal disorders comes from epidemiological studies, clinical case analyses, and short-term effects (Armstrong, Fine, Radwin, & Silverstein, 1987). Vibration stimulates muscle contraction, which is called a tonic vibration reflex. It also reduces tactility and affects the amount of force exerted to hold or manipulate a given object (Armstrong et al., 1987). For example, when using vibrating tools, excessive force may be needed to hold the tools, thus increasing the risk of a tendon or nerve disorder (Armstrong et al., 1987). This close relationship between vibration and force makes it very difficult to determine their relative contribution in epidemiological and clinical studies (Armstrong et al., 1987). In musicians, vibration may not constitute a significant risk factor given that the only vibration that occurs is generated by a rapid movement of the musician's finger on a specific string. Thus, it seems like the musician is not suffering the effects of vibration but generating the vibration itself.

2.4 Psychosocial Factors

Aside from the physical factors, psychosocial factors are also assumed to play an important role in the development of musculoskeletal disorders. The term psychosocial can include three separate domains: factors associated with work and job environment, individual characteristics, and factors associated with extra-work environment. Interactions among factors within each of these domains constitute what is referred to as a "stress process," the results of which are thought to impact upon both health status and job performance (P.M. Bongers, de Winter, Kompier, & Hildebrandt, 1993). Bongers et al (2002) performed a systematic literature study on the relationships between psychosocial factors and shoulder, elbow, hand or wrist problems. The review included one prospective cohort study, one case control study and 26 cross sectional studies. Consistent associations with upper limb disorders were found for perceived high work stress and non-work-related work stress and there were also some indications for an association between upper limb problems and high job demand (P.M. Bongers et al., 2002).

There are four reasonable explanations for the relationship between psychosocial factors and musculoskeletal disorders. The first one is that psychosocial demands may produce increased muscle tension and exacerbate task-related biomechanical strain. Second, psychosocial demands may affect awareness and reporting of musculoskeletal symptoms, and/or perceptions of their cause. Third, initial episodes of pain based on a physical insult may trigger a chronic nervous system dysfunction, physiological as well as psychological, which perpetuates a chronic pain process. Finally, in some work situations, changes in psychosocial demands may be associated with changes in physical demands and biomechanical stresses, and thus associations between psychosocial demands and MSDs occur through either a causal or effect-modifying relationship (NIOSH, 1997).

P.M. Bongers et al. (1993) concluded that psychosocial factors like monotonous work, high perceived workloads and time pressure are related to musculoskeletal disorders as well as low job control and lack of social support. Loo, Lu, and Bloor (2003) showed that in general, increased time pressure, increased muscle activation, force and wrist deviation; and increased workload increased key strike force. A considerable amount of studies conclude that it is likely that some (work-related) psychosocial factors are associated with musculoskeletal problems, but the evidence on specific associations is still inconclusive.

Psychosocial factors also affect musicians, i.e. job demands, which exert an influence on the musician’s health (in the case of the musician, job demands refer to performing well in order to thrive and have a successful career). Unfortunately, most of the studies linking psychosocial factors found in professional musicians and PRMDs are anecdotal and lack scientific validity.

2.5 Multiple physical risk factors

When grouped together, biomechanical risk factors can highly increase the risk for musculoskeletal disorders. Marras and Schoenmarklin (1993) attempted also to determine the hierarchy of the biomechanical factors responsible for carpal tunnel syndrome: they found that velocities and accelerations of the wrist in the sagittal plane were the factors most correlated with the development of this syndrome. In a study conducted by Malchaire et al (1997), the association between risk factors from the workplace and the development of wrist disorders identified force as the most significant risk parameter followed by the velocity of movement in flexion-extension and repetitiveness. Repetition and awkward postures have also been shown to increase the risk for musculoskeletal disorders. A study by Kuorinka and Forcier (1995) showed that the combination of awkward postures and repetitive motions is particularly stressful and may contribute to muscle damage, tendonitis, or nerve damage. Thus, the combination of multiple biomechanical factors, particularly of posture and repetition, may increase the risk for the development of musculoskeletal disorders in musicians. However, it is difficult to determine their relative contribution to the onset of the disorder.

Table 2 (NIOSH, 1997) summarizes the strength of evidence supporting a relationship between work and neck and upper limb musculoskeletal disorders. The biomechanical risk factors shown to have a positive relationship with neck and upper limb musculoskeletal disorders were combinations of repetition, force and postural work factors for elbow musculoskeletal disorders and hand/wrist tendinitis. A combination of these factors and vibration has a positive relationship with carpal tunnel syndrome. A causal relationship is very likely between intense and long exposure to biomechanical risk factors and the development of disorders in these regions.

Table 2.1: The work-relatedness of musculoskeletal disorders: physical work risk factors (NIOSH, 1997)

Body part, risk factor	Strong evidence	Evidence	Insufficient Evidence	Evidence of no effect
Neck and neck/shoulder				
Repetition		✓		
Force		✓		
Posture	✓			
Vibration			✓	
Shoulder				
Repetition		✓		
Force			✓	
Posture		✓		
Vibration			✓	
Elbow				
Repetition			✓	
Force		✓		
Posture			✓	
Combination	✓			
Hand/Wrist				
Carpal Tunnel Syndrome				
Repetition		✓		
Force		✓		
Posture			✓	
Vibration		✓		
Combination	✓			
Tendonitis				
Repetition		✓		
Force		✓		
Posture		✓		
Combination	✓			
Hand Vibration Syndrome				
Vibration	✓			

2.6 Playing through pain

In spite of the high risks associated with playing a musical instrument, many musicians are willing to play through pain even at a very young age (Park, Guptill, & Sumsion, 2007). The risks do not stop musicians from pursuing their love of performing and playing their instruments (Park et al., 2007). Many musicians believe that pain is inherent in the level of performance they try to achieve (Amadio & Russoti, 1990), and sometimes musicians may even feel they are responsible for their injuries and choose to ignore the pain either consciously or subconsciously (Alice G. Brandfonbrener, 1991). Injuries may be interpreted as an indication of inferior talent and overall failure as a performer (A.G. Brandfonbrener, 2006). For others, financial limitations, lack of health insurance, fear of loss of employment or career advancement may contribute to their tendency to play through pain (Dommerholt & Norris, 1997). Thus, there is a need to understand the importance and the contribution of the physical risk factors to the development of musculoskeletal injuries in musicians. Unfortunately, research on the effects of multiple biomechanical factors on the development of injuries in musicians is scarce.

2.7 Research gaps

As mentioned above, musicians are at a high risk for developing musculoskeletal disorders given the physical challenges they face on a daily basis while playing their instrument. Thus, there is a need to understand how risk factors are correlated with the development of pain or discomfort and therefore with the development of disorders. From the four biomechanical risk factors, posture and repetition seem to have the highest effect on musicians due to the fact that they sustain awkward postures for long periods of time and that the act of playing is repetitive itself. Yet, no study has attempted to understand postural changes and to document the number of repetitions to have a clear idea of how these relate to the onset of pain or discomfort.

CHAPTER 3

METHODS

The objective of this research is to document the changes in posture and the number of wrist and forearm repetition among violin players during an experiment session as well as to evaluate the perception of discomfort and pain felt by musicians in the past and document how many have been diagnosed with a disorder. This will help determine differences between musicians in terms of the levels of pain and/or discomfort and how this pain relates to other factors like years of playing or hours practiced per day. Ultimately, the research will try to determine a possible relationship between posture and repetition with pain/discomfort.

3.1 Participants

All violin and viola players from the two violin and viola classes at LSU, as well as other local violin and viola players were sent the recruitment email shown in Appendix A; all of them were above the age of 18. The email sent had a link to a survey which was approved by the LSU IRB. The survey included a number of demographic questions as well as a discomfort survey. At the end of the entire survey, participants were asked if they would be willing to participate in a follow-up experiment. Participants who agreed provided contact information and read the consent form embedded in the survey. The survey took approximately two minutes to complete. Out of the 39 violin/viola players contacted 18 (46%) completed the survey and 12 (31%) agreed to participate in the follow up experiment. Out of the 18 survey respondents, 15 were students at LSU, 3 were professional musicians working in the Baton Rouge area. Also, only 2 of the survey respondents were violists, the rest were violinist. These participants were informed of the selection and were asked to bring both their own instrument and a musical piece they were currently working on to the experiment.

Participants who agreed to participate in the experiment but rated pain at a level of 9 or above (on a scale of 0 to 10 with 10 being the worst pain) were excluded from the experiment as it could represent a health risk. Luckily, none of the participants reported pain above a 9 rating and were all included in the experiment.

3.2 Equipment

Posture was measured using a joint angle measurement system of electrogoniometers. Twin axis goniometers (Model SG65; Biometrics, Ltd.; Gwent, UK) were used to simultaneously measure wrist flexion/extension and radial/ulnar deviation. Data was stored on the data logger and later downloaded to a personal computer using Biometrics DataLOG PC Software 8.0 (Biometrics, Ltd.; Gwent, UK). For the measurement of forearm pronation/supination, single axis torsiometers (model Q110; Biometrics, Ltd.; Gwent, UK) were used. The working mechanism is the same for both types of sensors. Between the two endblocks inside the protective spring there is a composite wire that has a series of strain gauges mounted around the circumference. As the angle between the two ends changes the change in strain along the length of the wire is measured and this is equated to an angle. The design is such that only angular displacements are measured. If the two ends move linearly relative to each other, within the limits of the sliding endblock, without changing the relative angles between them, then the outputs remain constant.

3.3 Electrogoniometer setup

With the subject's shoulder in abduction at 90 degrees and elbow flexed at 90 degrees, such that the forearm is close to full pronation the distal endblock was attached to the dorsal surface over the third metacarpal with the center axis of the hand and endblock coincident. While fully flexing the wrist the goniometer was extended and the proximal endblock was attached to the forearm so that when viewed from the dorsal plane the axes of the forearm and endblock were coincident.

3.4 Torsiometer setup

The two endblocks of the torsiometer were attached to the forearm with the slider mechanism approximately midway between the two extremes. Measurement of pronation/supination was made in the Z axis.

Figures 3.1 and 3.2 show the proper setup of both the electrogoniometers and torsiometers on one of the participants.

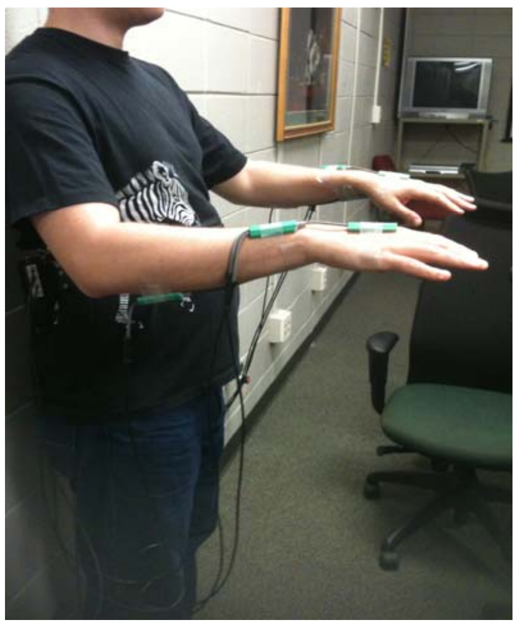

Figure 3.1: Side view of electrogoniometers on both lower arms

Figure 3.2: Front view of placement of both electrogoniometers and torsiometers on both lower arms

3.5 Independent Variables

The independent variables were all the variables that accounted for pain/discomfort and were measured by:

- Number of pain days in a year
- Level of pain/discomfort that participants felt at the beginning of the experiment (absolute measure of pain/discomfort),
- Level of pain/discomfort that participants felt after the experiment (relative measure of pain/discomfort),
- Difference in the level of pain/discomfort that participants felt after the experiment and before the experiment.

3.6 Dependent Variables

The dependent variables were: hours practiced a week, years playing, frequency of past pain, gender, dominant hand, posture (left ulnar, left radial, left flexion, left extension, left pronation, left supination, right ulnar, right radial, right flexion, right extension, right pronation, right supination) and number of repetitions (left radial/ulnar, left flexion/extension, left pronation/supination, right radial/ulnar, right flexion/extension, right pronation/supination).

3.7 Procedure

On the day of the experiment, participants were asked to read and sign the same consent form they read when completing the online survey. A verbal explanation of the experiment was also given and participants had the opportunity to ask questions. Following this, participants were shown a body diagram called a Body Discomfort Map (BDM) and were asked to give a rating from 0-10 based on the BORG CR10 scale (appendix B). This tool developed by Corlett and Bishop (1976) has been used to evaluate a respondent's direct experience of discomfort the upper limbs. Also, based on the research of Chung, Lee, and Kee (2003) and Hughes (2004) this scale has been used to rate discomfort and pain. The participants filled the BDM depending on the level of pain/discomfort felt on the upper limbs (upper arm, lower arm, elbows, hands, and wrists) at that moment (appendix B). After the BDM was filled out, the researcher taped the electrogoniometers and torsiometers to the participant's hands and forearms, respectively. The sensors were taped to the participant's forearm and hand using double-sided adhesive tape as well as regular tape to secure the whole sensor and interconnect lead. After the sensors were taped to the participant's hands and forearms, the participant was asked to warm up with scales of choice for 10 minutes. Following the warm-up period, participants were asked to play a musical piece they have been working on for 30 minutes. This sequence of events was used to mimic a typical practice session. During the 30 minutes of practice, the researcher stopped the participant every 5 minutes to assess if the participant was experiencing any discomfort in the upper limbs. The participant was instructed to say the part of the upper limbs where the discomfort was felt as well as the rating assigned based on the BORG CR10 scale. At the end of the 30 minutes, participants were asked to mark another Body Discomfort Map using the Borg CR10 scale identical to the one completed at the beginning.

3.8 Data Analysis

All the angles of displacement obtained were stored on the data logger and later downloaded to a desktop computer using Biometrics DataLOG PC Software 2.0 (Biometrics, Ltd.; Gwent, UK). To document the number of repetitions, data from the angles of displacement was analyzed to see if a specific type of motion was identified by repetitive deviations. The data recorded (angles of displacement) in the USB inside the Data Logger was downloaded and saved into a desktop computer and later exported to an excel worksheet. The raw data displayed 6 columns of numbers; each column representing a channel (4 channels for the electrogoniometers and 2 for the torsiometers) and each number representing an angle between -180° and 180°. The sampling rate for the data storage can vary from 1 sample/second up to 20,000 samples/second. For this study, the sampling range was setup for 1000 angles of displacement (samples) per second. A sampling rate of 1000 samples/second was selected as it seemed like a good middle ground for capturing fast signals and at the same time not result in large quantity of data that does not change very often. Figure 4 displays an example of how the output with the 6 columns (for the 6 channels) of the angles of displacement. Table 3.1 displays 6 columns of data, each column has a heading representing the three planes of movement (R/U for Radial/Ulnar, F/E for Flexion/Extension and P/S for Pronation/Supination). As seen, the values fell between -180° and +180° and some values were positive and some negative. The positive or negative signs for the angles of displacement correspond to the direction of motion. Positive values correspond to ulnar deviation, wrist extension and pronation motions; negative values to radial deviation, wrist flexion and supination motions.

Table 3.1: Example of data output

R/U	F/E	P/S	F/E	R/U	P/S
14.1	16	-41.4	-9.8	3.3	23.3
14.3	15.9	-41.4	-10.2	4.3	22.3
14.3	16	-41.4	-9.9	5.1	22.7
14.2	16	-41.4	-10	6	22.9
14.3	15.9	-41.4	-10.6	7	23.3
14.3	15.9	-41.4	-10.8	7.9	23.9
14.3	16	-41.3	-10.8	8.7	24.6
14.4	16	-41.3	-10.8	9.4	24.7
14.3	16.2	-41.2	-10.9	10	25.1
14.2	16.1	-41.1	-10.5	10.6	25.7
14.1	16.1	-41.1	-10	11.2	26.8
14.1	16	-41.1	-9.6	11.6	28
14	16	-41	-9.2	12	28.9

Specific data analyses were carried out corresponding to each abovementioned objective. For objectives 1 and 2, descriptive statistics were computed for each type of motion (radial/ulnar deviation, flexion/extension and pronation/supination) as well as for the sets of pain/discomfort ratings (before the experiment, after the experiment session and the change throughout the experiment session) for each participant. These descriptive statistics were: maximum and minimum value, mean, and median, standard deviation, 25th and 75th percentile. A paired t-test was conducted to determine significant differences between the ratings of discomfort after and before the experiment session.

The Biometrics DataLog Software was used to determine the number of repetitions. The software determines repetitive motion when a certain group of angles constantly repeat within a trace (column). Angles above 3.5º were considered to be a repetition in all planes, x, y and z. Movements in relatively static tasks have been captured using a threshold of 3.5° in other industrial settings such as fish processing (Bristow, 1986). The group of angles that repeat within a trace will be considered a repetitive motion of either the wrist or forearm depending on the channel where the pattern was found. In order to count as a repetition, the trace must change direction twice in succession. The average of the number of repetitions per channel for all participants was calculated and graphed using Excel.

For objective 3, information from the electronic survey on the frequency of pain helped develop a count of the number of respondents that have felt past pain and a count of and those who have been diagnosed with a musculoskeletal disorder as well as the type of disorders.

For objectives 4 and 5, Pearson correlation coefficients were calculated to determine if there were any significant correlations between the dependent variables (hours/day of practice, frequency of pain, years of playing the violin, posture, and repetition) and the independent variables (PainDays, BeforeDiscomfort, AfterDiscomfort, and ΔDiscomfort) as well as between the independent variables. In this analysis, all dependent variables were numerical, except gender and dominant hand. For gender a 0 was given for males and a 1 for females; similarly, for dominant hand a 0 was given to the left hand and a 1 to the right hand. In all analysis a statistical significance level of $p<0.05$ was used.

Using data from the survey, a regression analysis was conducted to determine the relationship between "PainDays" (independent variable) and the dependent variables (hours/day of practice, frequency of pain, years of playing the violin, gender, dominant hand, posture and repetition). The variable "PainDays" represented the number of days a participant experienced pain/discomfort within a year and was obtained from the frequency of pain. For participants who reported an everyday frequency of pain/discomfort, PainDays was given a value of 365. Participants who experienced a pain/discomfort frequency of 1-2 times a week were assigned 78 days (1.5*52 weeks); participants with a pain/discomfort frequency of 3-4 times a week, PainDays was given a value of 182 (3.5*52); finally, PainDays was given a value of 12 for participants experiencing pain/discomfort once a month.

The variable “BeforeDiscomfort” was a value (rating) from 0 (nothing at all) to 10 (extremely strong pain/discomfort) that participants gave to the level of pain/discomfort they felt at the beginning of the experiment session. Likewise, “AfterDiscomfort” represented a value participants gave to the level of pain they felt at the end of the experiment session.

The regression model used was as follows:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 + \beta_7 x_7 + \beta_9 x_9, \dots, + \beta_{25} x_{25} + \varepsilon$$

(equation 1)

Where “y”: PainDays

$\beta_0, \beta_1, \beta_2, \beta_3, \dots, \beta_{25}$ are constants determined by the regression analysis

“x_1”: hours/day of practice,

“x_2": frequency of pain,

“x_3”: years of playing the violin,

“x_4”: gender,

“x_5”: dominant hand,

“x_6”: left radial,

"x_7”: left ulnar,

"x_8”: left flexion,

"x_9”: left extension,

"x_{10}”: left pronation,

"x_{11}”: left supination,

"x_{12}”: right radial,

"x_{13}”: right ulnar,

"x_{14}”: right flexion,

"x_{15}": right extension,

"x_{16}": right pronation,

"x_{17}": right supination,

"x_{18}": left radial/ulnar,

"x_{19}": left flexion/extension,

"x_{20}": left pronation/supination,

"x_{21}": right radial/ulnar,

"x_{22}": right flexion/extension,

"x_{23}": right pronation/supination,

"x_{24}": AfterDiscomfort, and

"x_{25}": BeforeDiscomfort

A second model was used to determine the relationship between "AfterDiscomfort" (the pain/discomfort felt after the experiment session) and all the above-mentioned dependent variables. The model used was:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 + \beta_7 x_7 + \beta_9 x_9, \dots, + \beta_{24} x_{24} + \varepsilon$$

(equation 2)

where

"y": AfterDiscomfort

"x_1": hours/day of practice,

"x_2": frequency of pain,

"x_3": years of playing the violin,

"x_4": gender,

"x_5": dominant hand,

“$x_6, \dots, x_{17}$”: posture (see previous),

“$x_{18}, \dots, x_{23}$”: repetition (see previous), and

“x_{24}”: BeforeDiscomfort

A third regression model was used to determine the relationship between “ΔDiscomfort”, the difference in pain/discomfort obtained from subtracting the pain/discomfort after the experiment session from the pain/discomfort before the experiment session, and all the dependent variables. The model used was:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 + \beta_7 x_7 + \beta_9 x_9, \dots, +\beta_{25} x_{25} + \varepsilon$$

(equation 3)

where

“y”: ΔDiscomfort

“x_1”: hours/day of practice,

“x_2": frequency of pain,

“x_3”: years of playing the violin,

“x_4”: gender,

“x_5”: dominant hand,

“$x_6, \dots, x_{17}$”: posture (see previous),

“$x_{18}, \dots, x_{23}$”: repetition (see previous),

“x_{24}”: AfterDiscomfort, and

“x_{25}”: BeforeDiscomfort

Due to the large amount of variables involved in these regression models, stepwise regression was used. Through an iterative process this type of regression only kept the statistically significant ($\alpha = 0.05$) variables in the model while the rest were discarded.

To interpret the regression results the R^2 value measured how much of the variability in the outcome is accounted for by the dependent variables while the P-values measured the significance of each correlation among variables. This helped determine which dependent variables (predictors) contributed substantially to the model's ability to predict the outcome. In summary, it helped determine which dependent variables were associated with higher levels of pain.

CHAPTER 4

RESULTS

Objective 1 and 2: Document the postural changes and number of wrist and forearm repetitions among violin players during an experiment session; evaluate the perception of discomfort and pain felt by musicians before and after a short experiment session.

Out of eighteen survey respondents, eight were females, ten were males. Four were left handed. The average number of years playing the violin was 18.3 years (7.08); on the average participants practiced 3.94 hours (1.63) per day. Ten participants reported having pain/discomfort "once a month"; four reported having pain/discomfort "1-2 times a week"; two participants reported having pain/discomfort "everyday" and two participants reported pain/discomfort "3-4 times a week". Of these eighteen survey respondents twelve agreed to participate in the follow up experiment.

Table 4.1 displays the descriptive statistics for the postural changes for the 10-minute warm-up period for the twelve experiment participants. Each number under the column "mean" corresponds to the average of all of the angles of displacement in a particular direction for both the left and right sides of the upper limbs. The positive or negative signs for the angles of displacement correspond to the direction of motion. Positive values correspond to ulnar deviation, wrist extension and pronation motions; negative values to radial deviation, wrist flexion and supination motions. Table 4.2 shows the descriptive statistics for the postural changes for the 30-minute practice session. The descriptive statistics computed were the maximum and minimum value, mean, median, standard deviation, 25th and 75th percentile. Figure 4.1 and 4.2 also display boxplots of the descriptive statistics for both the 10 min and 30 min sessions.

Table 4.1: Descriptive statistics for the postural changes for the 10 min warm up period

Posture	Mean(°)	Max(°)	Min(°)	SD(°)	25th percentile(°)	75th percentile(°)
LeftExtension (LE)	-13.1	-0.1	-67.2	9.81	-18.9	-4.9
LeftFlexion (LF)	22.6	77.2	0	14.9	10.5	32.6
LeftPronation (LP)	6.48	41.8	0	6.56	1.7	9
LeftRadial (LR)	13.4	30.7	0	6.65	8.4	19
LeftSupination (LS)	-21.3	-0.1	-58.5	9.73	-27.9	-14.4
LeftUlnar (LU)	-10.8	-0.1	-33.6	6.67	-15.5	-5.4
RightExtension (RE)	-21.4	-0.1	-64.3	14.01	-31.9	-9.4
RightFlexion (RF)	16.4	57.4	0	10.70	7.7	23.6
RightPronation (RP)	6.39	63.1	0	6.29	2	8.8
RightRadial (RR)	12.3	35.2	0	8.79	4.5	20.7
RightSupination (RS)	-16.0	-0.1	-41.1	8.48	-23.1	-9
RightUlnar (RU)	-13.0	-0.1	-42.6	7.59	-18.4	-7

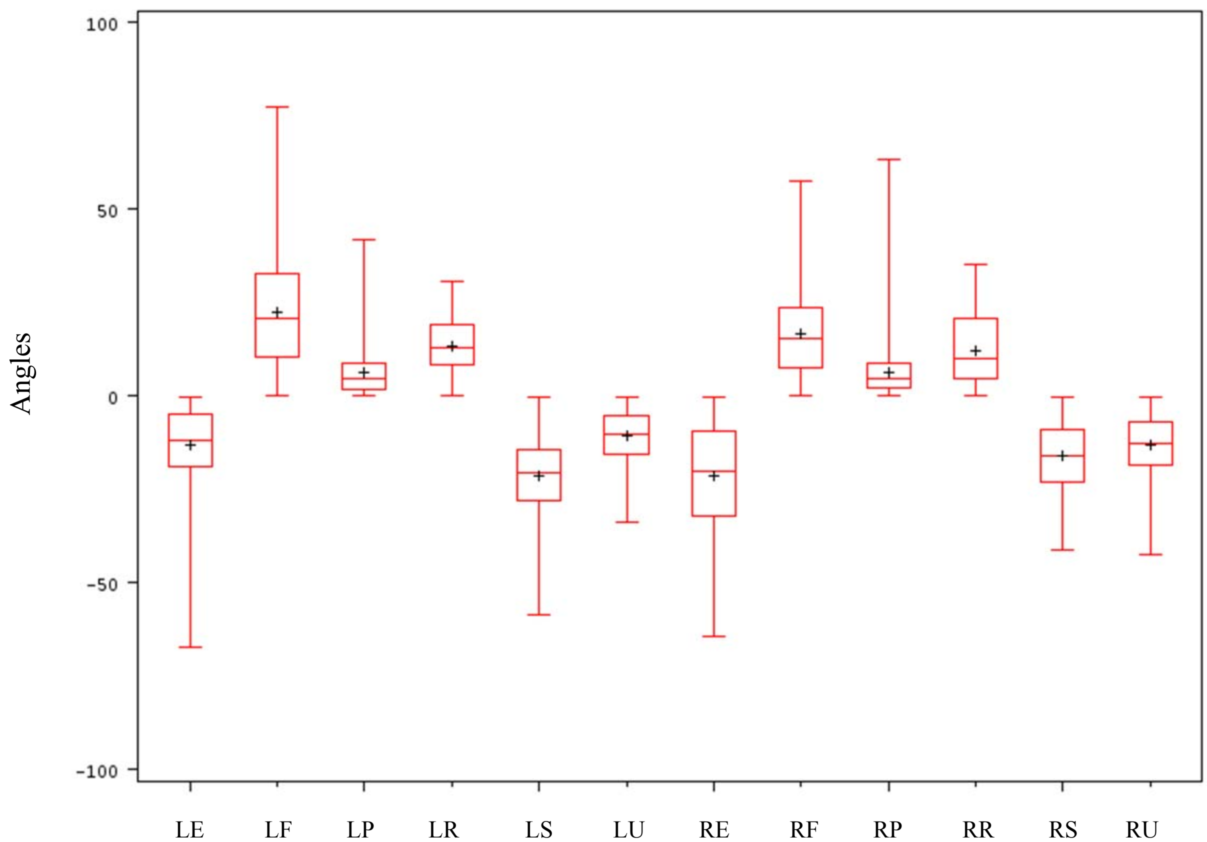

Figure 4.1: Boxplot for all twelve posture variables for the 10 min warm up period

Table 4.2: Descriptive statistics for the postural changes for the 30 min practice session

Posture	Mean(°)	Max(°)	Min(°)	SD(°)	25th percentile(°)	75th percentile(°)
LeftExtension (LE)	-14.2	-0.1	-80.6	12.0	-18.3	-5.9
LeftFlexion (LF)	25.7	84.9	0	15.7	13.5	34.7
LeftPronation (LP)	7.94	51.1	0	6.63	3.2	10.4
LeftRadial (LR)	14.3	32.3	0	6.12	10.1	18.6
LeftSupination (LS)	-21.4	-0.1	-51	8.68	-28.2	-16
LeftUlnar (LU)	-13.4	-0.1	-40.6	7.12	-13.7	-2.9
RightExtension (RE)	-17.4	-0.1	-77.8	12.3	-26	-7
RightFlexion (RF)	15.9	68.5	0	10.9	7	23.4
RightPronation (RP)	6.98	65.6	0	7.54	1.9	9.2
RightRadial (RR)	10.2	38.2	0	7.28	4.1	15
RightSupination (RS)	-15.0	-0.1	-38.6	8.28	-22.1	-8.2
RightUlnar (RU)	-12.5	-0.1	-39.4	7.19	-17.1	-6.9

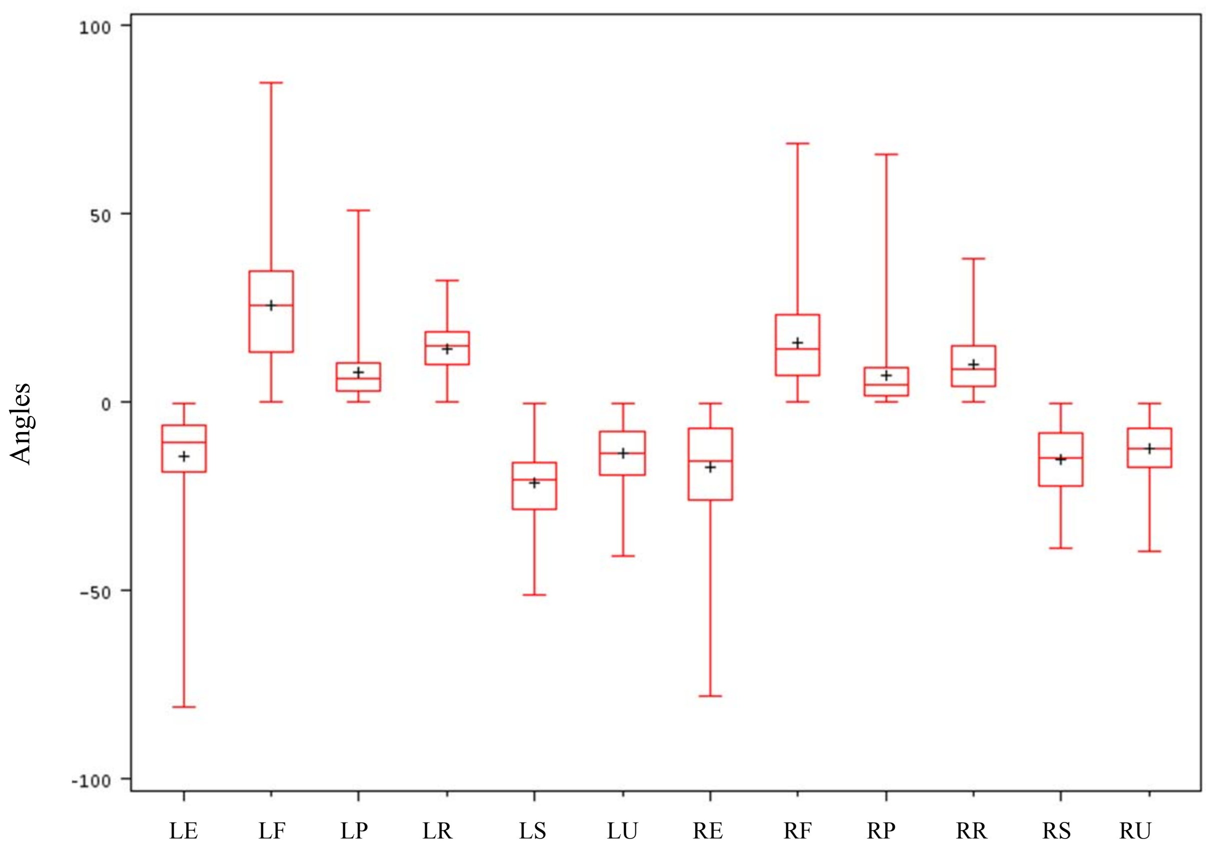

Figure 4.2: Boxplot for all twelve posture variables for the 30 min practice session

When looking at the 75th percentiles of the movements in the Radial/Ulnar plane during the 10 minute warm up period, table 4 shows RightRadial at 20.7° (typical range of motion of the wrist in this plane is 20° (Rowe, Heck, & Hendryson, 1966)). The maximum value in this direction (35.2°) clearly exceeds the typical range of motion. In the Flexion/Extension plane, table 4 shows LeftFlexion with a 75th percentile of 32.6° (typical range of motion of the wrist in this plane is 70° (Rowe, Heck et al. 1965)) and a maximum value of 77.2° which exceeds the typical range of motion. Finally, in the Pronation/Supination plane, table 4 shows LeftSupination with a 75th percentile of 14.4° (typical range of motion of the forearm in this plane is 70° (Rowe, Heck et al. 1965)) with a maximum value of 58.5° (considering absolute values).

Likewise, during the practice session, table 5 shows LeftRadial with a 75th percentile of 18.6° and with a maximum value of 32.3° which goes beyond the typical range of motion; LeftFlexion as the highest in that Flexion/Extension plane of motion with a 75th percentile of 34.7° and a maximum value of 84.9° and finally, LeftSupination with a value of 16 as the 75th percentile depicting a maximum value of 51°.

Table 4.3 displays the means for the body discomfort ratings taken before and after the experiment session for each participant. The mean value for each participant was obtained across all the eleven body parts displayed on the diagram (neck, right shoulder, left shoulder, right upper arm, left upper arm, right lower arm, left lower arm, right wrist, left wrist, right hand, and left hand). Only five out of twelve participants started with no pain/discomfort. Also, only three remained at the same level of pain/discomfort after the session, while the rest increased.

After conducting a paired t-test, with 11 degrees of freedom, a t-value of 4 and a p-value of 0.0021 ($\alpha = 0.05$), there was a significant increase between the means of the pain/discomfort ratings before and after the experiment session.

Table 4.3: Mean ratings of pain/discomfort before, after the experiment session and their difference

Mean Body Discomfort Ratings			
Participant No.	**Before**	**After**	**Difference (After-Before)**
Participant 1	0	0.545 (1.214)	0.545 (1.214)
Participant 2	0.182 (0.405)	0.545 (1.214)	0.364 (0.809)
Participant 3	0	0.182 (0.405)	0.182 (0.405)
Participant 4	0	0.182 (0.603)	0.182 (0.603)
Participant 5	0	0.273 (0.905)	0.273 (0.905)
Participant 6	0.182 (0.603)	0.727 (1.009)	0.545 (0.406)
Participant 7	0.091 (0.202)	0.318 (0.462)	0.227 (0.260)
Participant 8	0	0	0
Participant 9	0.364 (0.809)	0.364 (0.809)	0
Participant 10	0.364 (0.809)	1 (1.414)	0.636 (0.605)
Participant 11	0.136 (0.234)	0.273 (0.647)	0.136 (0.413)
Participant 12	0.182 (0.603)	0.182 (0.603)	0

A table for the number of repetitions is also shown (Table 4.4). The software for the Biometrics equipment provided a count of repetitions for each two directions (radial/ulnar, flexion/extension and pronation/supination) for a total of 6 columns (three for the left side and three for the right side). This means that there is a column for repetitions on each axis; one for Radial and Ulnar (X axis), a second one for Flexion and Extension (Y-axis) and a third one for Pronation and Supination (Z-axis). Figure 4.3 shows that right Radial/Ulnar has the highest number of repetitions followed by Left Flexion/Extension.

Table 4.4: Average of the number of repetitions per channel for all participants

Repetition (Left)			**Repetition (Right)**		
R/U	F/E	P/S	R/U	F/E	P/S
122(92)	365(236)	71.5(119)	752(326)	330(170)	327(240)

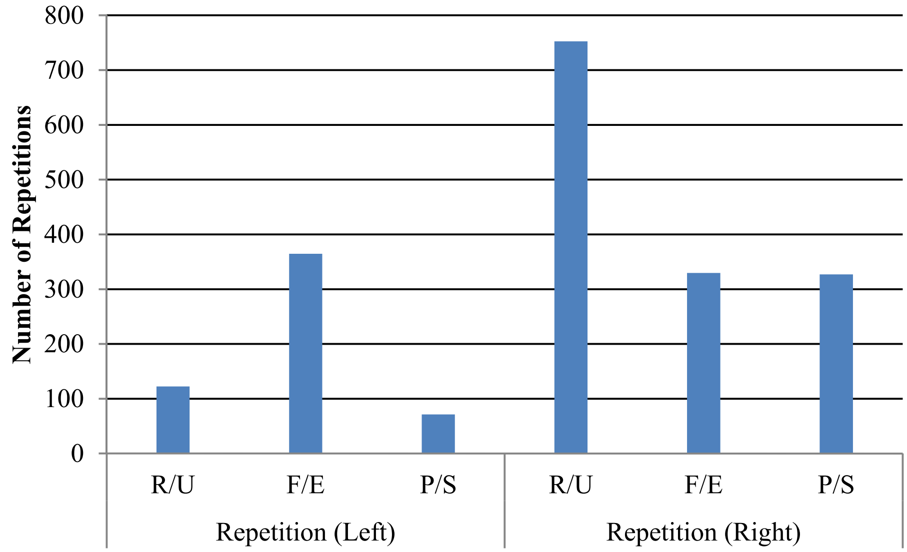

Figure 4.3: Average number of repetitions per channel

Objective 3: Document how many participants have experienced pain over a one year period and where as well as how many have been diagnosed with a PRMD.

From the 18 survey respondents, four had been diagnosed with a musculoskeletal disorder. The diagnoses for each of the participants were: (1) wrist cyst (2) tendonitis/bursitis (3) tendonitis and (4) tendonitis; cubital tunnel; muscular cramp; herniated discs in cervical spine; scoliosis. Table 4.5 shows the demographic information obtained from the electronic survey for all eighteen respondents. A horizontal line is used to separate the twelve respondents that agreed to participate in the experiment from the rest.

Table 4.5: Demographic information for all survey respondents

Survey Data					
No.	Gender	Dominant Hand	Number of years playing the violin	Hours of practice/day	Frequency of pain
P1	Female	Right	22	3	1-2 times a week
P2	Female	Left	13	5	1-2 times a week
P3	Male	Right	40	4	Once a month
P4	Male	Right	15	1	Once a month
P5	Male	Right	15	2	Once a month

(Table 4.5 continued)

No.	Gender	Dominant Hand	Number of years playing the violin	Hours of practice/day	Frequency of pain
P7	Male	Right	17	4	Once a month
P8	Male	Right	17	3	Once a month
P9	Male	Right	20	6	Everyday
P10	Female	Right	15	4	Once a month
P11	Male	Right	21	5	3-4 times a week
P12	Male	Right	13	1	1-2 times a week
P13	Male	Left	14	4	Once a month
P14	Female	Right	20	6	Once a month
P15	Female	Right	12	7	3-4 times a week
P16	Female	Right	18	5	Once a month
P17	Female	Left	27	4	Everyday
P18	Female	Left	8	4	1-2 times a week

The following list reports the results obtained from the survey on past pain/discomfort (within the last year):

- Left Upper Arm, 4 respondents with durations of 2 days, about a year, 1 month, and three weeks.
- Left Lower Arm, 1 respondent with duration of 3 months.
- Left Wrist, 3 respondents with durations of 2 hours, 10 days, and 3 months respectively.
- Left Hand, 4 respondents with durations of 9 months (on and off), 2 months, 2 weeks, and 3 months respectively.
- Right Upper Arm, 1 respondent with 3 month duration.
- Right Lower Arm, 1 respondent for duration of 1 year.
- Right Wrist, 1 respondent for duration of 1 year.
- Right Hand 1 respondent for duration of 1 year.

- Finally, 8 respondents reported pain/discomfort in other regions. Neck was mentioned three times; Left Shoulder was mentioned four times; Right Shoulder was mentioned three times; Back was mentioned once; behind the right shoulder blade and between the neck and the shoulder blade were each mentioned once.

Objectives 4 and 5: Determine possible correlations between dependent variables (number of years playing the violin, hours of practice/day, frequency of pain, gender, dominant hand, posture and repetition) and independent variables as well as between independent variables. Determine possible relationships between posture and repetition with pain/discomfort.

Table 4.6 contains the correlations between the independent (pain/discomfort) and dependent variables. The independent variables accounting for pain are PainDays (number of days in the year with pain/discomfort), ΔDiscomfort (difference in pain/discomfort after and before the experiment session), AfterDiscomfort (pain/discomfort reported after the 40 minutes of experiment session), and BeforeDiscomfort (pain/discomfort reported before the 40 minutes of experiment session). Each cell contains an R-value. Marked with an asterisk are the significant correlations using α value of 5%.

Table 4.6: Pearson Correlation Coefficients between all independent and dependent variables (*p<0.05)

Pearson Correlation Coefficients				
	PainDays	**ΔDiscomfort**	**AfterDiscomfort**	**BeforeDiscomfort**
Hours of practice/day	0.603*	0.032	0.275	0.51
Years playing	-0.009	0.008	-0.12	-0.257
LeftRadial Posture	-0.469	0.437	0.282	-0.141
LeftUlnar Posture	-0.525	0.347	0.129	-0.305
LeftFlexion Posture	-0.177	0.334	0.148	-0.244
LeftExtension Posture	-0.358	0.226	0.237	0.112
LeftPronation Posture	-0.161	-0.087	-0.19	-0.245
LeftSupination Posture	0.51	-0.659*	-0.415	0.232
RightRadial Posture	-0.201	0.668*	0.553	0.034
RightUlnar Posture	0.219	-0.488	-0.358	0.07

(Table 4.6 continued)

	PainDays	**ΔDiscomfort**	**AfterDiscomfort**	**BeforeDiscomfort**
RightFlexion Posture	0.686*	-0.376	-0.107	0.397
RightExtension Posture	0.406	-0.278	-0.197	0.054
RightPronation Posture	-0.137	-0.146	-0.204	-0.178
RightSupination Posture	-0.094	0.166	0.258	0.254
BeforeDiscomfort	0.54	0.149	0.608*	1
AfterDiscomfort	-0.053	0.875*	1	0.608*
Left_R/U_Repetition	0.756*	-0.159	0.184	0.638*
Left_F/E_Repetition	0.633*	-0.388	-0.152	0.324
Left_P/S_Repetition	0.222	-0.52	-0.43	-0.025
Right_R/U_Repetition	-0.469	0.705*	0.47	-0.196
Right_F/E_Repetition	-0.238	0.596*	0.464	-0.029
Right_P/S_Repetition	-0.43	0.556	0.231	-0.439
PainDays	1	-0.395	-0.0529	0.54
ΔDiscomfort	-0.395	1	0.875*	0.149
AfterDiscomfort	-0.0529	0.875*	1	0.608*
BeforeDiscomfort	0.54	0.149	0.608*	1

From Table 4.6:

- Higher number of pain days was associated with more hours of practice/day ($p = 0.0379$).
- Higher supination of the left arm was significantly associated with a bigger change in discomfort during the experiment (p-value= 0.0198).
- Higher radial movement of the right wrist resulted in a higher change in discomfort throughout the experiment (p-value= 0.0175).
- Higher values for flexion of the right wrist depicted a bigger number of pain days in a year (p-value= 0.0138).
- The higher the ratings of pain/discomfort (AfterDiscomfort) after the experiment the higher the ratings of pain/discomfort before the experiment (BeforeDiscomfort) (p-value= 0.0358).

- The change in pain/discomfort during the experiment was significantly associated with the rating of pain/discomfort after the experiment (p-value= 0.0002); the higher the pain/discomfort after the experiment, the higher the change in pain/discomfort through the experiment.
- A higher the number of repetitions of the left hand in the Radial/Ulnar plane was associated with a higher number of pain days (p-value= 0.0044).
- Similarly, a higher number of repetitions of the left hand in the Flexion/Extension plane was significantly correlated with a higher number of pain days (p-value= 0.0272).
- The higher the number of repetitions of the right hand in the Radial/Ulnar plane the higher the change in pain/discomfort was (p-value= 0.0104).
- A higher number of repetitions of the right hand in the Flexion/Extension plane was significantly correlated with a higher number of pain days (p-value= 0.0409).

Table 4.7 shows the results of the regression analysis using AfterDiscomfort (pain/discomfort after the experiment session) as the dependent variable. Gender, BeforeDiscomfort, and Right_R/U_Repetition were selected as predicting variables.

Table 4.7: Stepwise regression analysis results on AfterDiscomfort

Parameter Estimates					
Parameter	**DF**	**Estimate**	**Standard Error**	**t Value**	**p-value**
Intercept	1	-0.146239	0.101149	-1.45	
Gender	1	0.252461	0.083694	3.02	0.0145
BeforeDiscomfort	1	1.227591	0.275384	4.46	0.0432
Right_R/U_Repetition	1	0.000415	0.000115	3.62	0.0068

Table 4.8 provides the output of the regression analysis ran between PainDays (dependent variable) and the rest of the variables. Left_R/U_Repetition (0.0044), RightPronation (0.0203), and AfterDiscomfort (0.0184) were significant in predicting the model meaning that level of pain/discomfort felt after the experiment session is associated with the repetitions of the

left hand in the radial/ulnar plane, by pronation of the right hand, and by level of pain/discomfort felt after the experiment session.

Table 4.8: Stepwise regression analysis results on PainDays

Parameter Estimates					
Parameter	**DF**	**Estimate**	**Standard Error**	**t Value**	**p-value**
Intercept	1	120.386749	38.040685	3.16	
RightPronation	1	-18.387856	4.052273	-4.54	0.0203
AfterDiscomfort	1	-139.967655	47.415668	-2.95	0.0184
Left_R/U_Repetition	1	1.202732	0.150964	7.97	0.0044

Finally, for the regression model using ΔDiscomfort (difference between pain/discomfort ratings after and before the practice session) as the dependent variable, Right_R/U_Repetition (0.0104) and Gender (0.0065) were selected for predicting the model. Consequently, the change in discomfort can be predicted by the number of repetitions of the right hand in the radial/ulnar direction and by gender (Table 4.9).

Table 4.9: Stepwise regression analysis results on Discomfort

Parameter Estimates					
Parameter	**DF**	**Estimate**	**Standard Error**	**t Value**	**p-value**
Intercept	1	-0.103608	0.085462	-1.21	
Gender	1	0.274344	0.077984	3.52	0.0065
Right_R/U_Repetition	1	0.000389	0.000108	3.59	0.0104

CHAPTER 5

DISCUSSION

The overall objective of this study was to document the changes in posture and the number of wrist and forearm repetitions among violin/viola players during an experiment session as well as to evaluate the perception of discomfort and pain felt by musicians in the past and document how many have been diagnosed with a PRMD. All of this would ultimately lead to discovering possible correlations between posture and repetition with pain/discomfort.

Data on the postural changes for each plane of motion (Radial/Ulnar, Flexion/Extension, Pronation/Supination) indicate that the left arm and wrist experience a higher range of motion. For both the 10 min warm up period and the 30 min practice session Left Flexion and Left Supination display the biggest postural displacement within their corresponding range of motion. Also, for the 30 min practice session, Left Radial displayed the biggest deviation in the x-plane (Right Radial for the 10 min warm up period). The recurrence of bigger postural changes on the left side of the lower arm and wrist agrees with the participant's responses on past pain; the largest number of accounts on past pain were reported on the left lower arm and hand.

The fact that the lower arm and wrist display more extreme postures indicates that playing the violin/viola may impose a higher physiological load on the left arm and might indicate that workload may not be distributed symmetrically between both sides. In violin/viola players, the left hand performs finer motor movements while the right side carries out the bowing; meanwhile the neck and the shoulder are sustained in static postures. Maintaining these unnatural postures for long periods of time can lead to pain/discomfort given that the muscles become fatigued. This higher displacement of the left lower arm and wrist could lead to more pain/discomfort and result in the development of musculoskeletal disorders. Prolonged or frequent static muscular exertions have been associated with the occurrence of work-related musculoskeletal disorders (Chaffin, Andersson, & Martin, 1999) and could also lead to PRMDs. The lack of research on how physical risk factors affect the development of musculoskeletal disorders in musicians requires the current study to rely on results obtained from research in other highly hand intensive occupations. Thus, despite the lack of scientific validation of how posture affects the development of musculoskeletal disorders in musicians, literature shows that extreme or awkward postures are considered risk factors in the development of musculoskeletal disorders in manually intense occupations like typists. Extreme wrist postures during, e.g. computer mouse use, are associated with an increased risk of arm/hand symptoms and signs according to a couple of studies (Marcus et al., 2002; Tittirononda, Burastero, & Rempel, 1999). Hunting et al (1981) evaluated the association between awkward typing postures and discomfort and found an elevated self-reported pain (more than 10%) in the upper limbs among the 240 typists compared to the 55 control group (around 2%). Through medical examination, positive medical findings of pressure points at the muscles and tendons and forearm pain were three times higher for the typist and were linked to awkward postures (Hunting et al., 1981). In a cross sectional study conducted by Bergqvist et al (1995), no-neutral or extreme hand postures were associated with arm/hand discomfort among computer users.

From the Body Discomfort Maps, five out of twelve participants reported zero pain/discomfort at the beginning of the experiment session; only three remained at the same level of pain/discomfort, while the rest increased (9). Some of the participants reporting pain/discomfort at the beginning of the experiment session may have practiced their instrument prior to participating in the experiment, which could have led to some muscle strain. Even though the experiment session was only 40 minutes long, 9 out of 12 participants reported increasing pain/discomfort; this confirms that even "short" periods of practice can lead to increasing muscle strain and discomfort (the mean for the number of hours practiced a day was 3 hrs and 20 min). Another important factor to take into consideration is the practice-rest schedule. Although the experiment session did not have any scheduled breaks, participants were told and encouraged to take them as needed. They were told to stop to rest, turn pages or make annotations on their music. Most participants took short breaks to do either of these activities.

In general, literature shows that short rest breaks at regular intervals can reduce musculoskeletal discomfort and the risk of repetitive strain injury during intensive computer work (Henning et al., 1996). In a study by Balci (1999) 15 minute work followed by a 30 second rest and then 3 minute break after an hour of work, and 14 minute regular break after two hours of VDT work (denominated "15/micro") caused a lower increase in terms of discomfort in the upper extremities including neck, back and arm. Also, Asfour (1987) suggested a 30-min break in a 3.5 hrs of VDT work if productivity is considered. Perceived discomfort ratings have been found to be lower for the work periods with short pauses than the work periods without (Hagberg & Sundelin, 1986).

The prevalence for musculoskeletal discomfort/pain in this study was 100% given that all survey respondents reported a certain frequency of pain. This confirms what other studies have shown on the high rates of musculoskeletal symptoms and pain in musicians (Roach et al., 1994; Zaza, 1998). Out of the 18 survey respondents 4 (22.2%) had been diagnosed with a musculoskeletal disorder. Despite this number not being as high as expected, some musicians might still experience high level of pain and may potentially have a disorder but not have sought medical help.

The Biometrics software indicated that Right Radial/Ulnar had the highest number of repetitions followed by Left Flexion/Extension. Both sides of the lower arm and wrist have highly repetitive movements. Given that the fingering of the notes is done by the left hand, repetition is high especially in the flexion/extension plane. Multiple studies have shown that repetition is considered a risk factor for musculoskeletal disorders (Pitner, 1990; Ranney, Wells, & Moore, 1995). A study conducted by Byl and McKenzie (2000) showed that repetitive, rapid, alternating movements of the digits can be associated with a loss of motor control over time. However, other studies do not report repetitiveness as a predictor of musculoskeletal disorders (Malchaire, Cock, & Robert, 1996). Malchaire et al. (1996) found that the prevalence of wrist disorders was significantly associated with wrist angles in deviation and forces exerted but repetitiveness did not appear to play an additional role. However, for this study repetition was considered to be one of the risk factors associated with the development of musculoskeletal disorders in musicians along with posture. The interaction and presence of both risk factors could increase the onset of pain and discomfort among musicians confirming Kuorinka and Forcier's (1995) study on how the combination of awkward postures and repetitive motions is particularly stressful and may contribute to muscle damage, tendonitis, or nerve damage.

Results from the Pearson correlations between variables showed hours of practice per day significantly correlated with pain days/year which implies that more hours of practice is associated with more pain. In order to achieve a goal (learning or mastering a musical piece), musicians might practice for long periods of time with few or no breaks at all which may contribute to pain/discomfort. Some musicians may even play through pain or discomfort and may even attribute this pain to lack of proper technique. Some may feel that pain is their fault and avoid admitting it since no one wants to hire an injured musician (Sen, 1991). In general, musicians tend to be hesitant to report their injuries because of the stigma of being an injured musician who has impaired playing capability (Dunlap-Ward, 2001). Also, in this work no correlation was found between the number of years playing the violin and pain/discomfort which confirms another study by Dunlap-Ward (2001). In her study, no relationship was found between the number of musculoskeletal complaints and the experience level (measured in the number of years playing an instrument) which indicates that discomfort and pain occur independently of experience.

Results from the regression analysis showed Gender, BeforeDiscomfort, and Right_R/U_Repetition (repetitions in the radial/ulnar plane for the right hand) as predictors for the level of pain/discomfort felt after the experiment session meaning that these three factors have an influence in the level of pain/discomfort felt after the experiment. Higher repetitions of the right hand in the radial/ulnar plane could result a higher level of pain; the level of pain/discomfort experienced before the experiment might also influence the level of pain/discomfort felt after a practice session.

Left_R/U_Repetition (repetitions in the radial/ulnar plane for the left hand), RightPronation, and AfterDiscomfort were found to be significant in predicting the number of days a participant had experienced pain/discomfort in a year. Higher repetitions of the left hand in the radial/ulnar plane could result a higher number of pain days in a year just like higher angular displacements of the right hand in pronation and the level of pain/discomfort after a practice session.

Finally, Right_R/U_Repetition and Gender were found to be predictive for the change in Discomfort (After-Before) a participant experiences. In the same way, as repetitions of the right hand in the radial/ulnar plane could result a higher level of pain, they could also influence the change in discomfort a musician experiences as a result of practice.

Repetitive motions of both hands were considered predictors on all three regression models, which confirm what several other studies have concluded about repetition and their relationship with pain/discomfort. Highly repetitive movements have been well-recognized risk factors for work related musculoskeletal disorders such as carpal tunnel syndrome, tendinitis, and deQuervain's syndrome (NIOSH, 1997).

Also, the fact that gender was a predictor for both the level of pain/discomfort after the experiment session and for the difference in pain/discomfort indicates that more attention should be given to this variable. Literature has shown how relative forces applied to a keyboard, normalized muscle activity of two forearm muscles, range of motion for the wrist and shoulder joints and external rotation of the shoulder are higher for women than men (Won, Johnson, Punnett, & Dennerlein, 2009) which could all lead to the development of musculoskeletal disorders. In another study, (Wahlstrom, Svensson, Hagberg, & Johnson, 2000) reported that women used higher relative forces (percentage of maximum voluntary contraction) and more non-neutral postures than men when operating a computer mouse during a text selection and deletion task indicating that women may be more susceptible to the development of musculoskeletal disorders. Thus, the study of gender differences is promising.

5.1 Limitations

One of the limitations of the study was the small number of participants; only 12 actually participated in the experiment. The power of statistical tests can be reduced when a small sample is used as this increases variability. For future research it is advisable to have a larger number of musicians and a more equitable gender distribution. This could help determine differences between genders (especially when this study shows gender as a predictive variable in determining the pain after a practice session and the change in pain/discomfort).

Another limitation was the length of the experiment session. Given that musicians practice for longer periods of time, sometimes for as long as 5 hours (the mean practice time for participants in this experiment was 3.94 hrs) the ratings for pain/discomfort after the experiment could have been underestimated.

The fact that each participant played a different piece could have had an effect on the pain/discomfort ratings as some of them might have played more difficult pieces (more demanding), while others might have played simpler pieces. Also, the number of repetitions could have been affected as faster pieces involve more repetitions than slower ones.

Future research could explore other physical risk factors like applied forces or vibration or a combination of both. Exploring different combinations of risk factors (i.e. posture and force, or repetition and force, or even force, posture and repetition) and their possible influence in the development of PRMSDs could be interesting. Also, combining physical and psychosocial risk factors could be an interesting approach given that musicians not only experience physical demands but undergo psychosocial demands, like time pressure, social stresses (lack of social support from peers) and high workload.

Future studies could also look at the differences in postural changes and repetition between genders as well as differences in how forces are applied. Other studies could focus on the difference in how both genders report pain/discomfort and which are the most affected body parts. Studies can also attempt to document postural changes in different instrument cohorts to determine which instrument could lead to higher displacements, or which postures cause more strain.

Results from all these studies could lead to determining recommended practices like work-rest schedules, warm-up techniques, or a better education of musicians on these potential disorders.

5.2 Conclusion

Musicians are at a high risk for the development of musculoskeletal disorders due to the repetitive nature of playing as well as the sustained exposure to unnatural postures. This study showed that the left side of violin/viola players could be more affected by discomfort/pain. Gender, the level of discomfort before the experiment and repetition of the right hand in the radial/ulnar plane were found to be associated with the level of discomfort. Repetitive motions of the left hand in the radial/ulnar plane, pronation of the right hand and the level of discomfort after the experiment were predictors of the number of pain days/year. Also, the change in discomfort was predicted by gender and repetitive motions of the right hand in the radial/ulnar plane. In summary, this study helped conclude that more extreme postural deviations, higher number of repetitions, and more hours of practice per day are associated with a higher level of discomfort/pain. Thus, the study provides empirical evidence of the need to incorporate good ergonomics practices by increasing awareness of proper posture, taking breaks and stretching exercises and the need to educate musicians on the potential risks and symptoms of PRMDs.

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APPENDIX A: RECRUITMENT EMAIL TEXT

Hello!

My name is Cristina Handal, graduate student from the Construction Management and Industrial Engineering Department at LSU. In fulfillment of my requirements as a master student, I am conducting thesis research which involves musicians, specifically violin players (students and professionals). The purpose of the study is to document the changes in posture and the number of wrist and forearm movements among violin players during a typical practice session. The study will also evaluate the perception of discomfort and pain felt by the musicians in the past and document how many have been diagnosed with a disorder. From this, we will be able to determine differences between musicians who have experienced pain and have been diagnosed against those who have felt pain but have not sought medical help as well as determine a possible correlation between posture and repetition with discomfort.

I would be very grateful if you would be willing to participate in my study. If you agree to do so, please complete the survey at the following link (SURVEY LINK). All the information provided is confidential.

If you have any questions you are free to contact me or my supervisor, Dr. Laura Ikuma at likuma@lsu.edu.

Thanks much.

APPENDIX B: PRELIMINARY ONLINE SURVEY

Dear Participant:

The purpose of this survey is to document the prevalence of discomfort and pain among student and professional musicians. This online survey will also be used selection tool to determine which musicians could participate in an experiment for the Construction Management and Industrial Engineering Department at LSU.

Completion of this survey does not require that you participate in the follow-up experiment, and we greatly appreciate you completing the survey and volunteering for the experiment if you choose.

Your answers to this online survey will be completely confidential and your identity will be protected. Only the researchers listed will have access to your responses. If you do not feel comfortable with any one question, you can skip it or refuse to continue completing the survey. Your participation is completely voluntary but greatly appreciated. By participating you will help us determine differences between musicians who have experienced pain and have been diagnosed against those who have felt pain but have not sought medical help as well as determine a possible correlation between posture and repetition with discomfort.

The purpose of the follow-up experiment is to document the changes in posture and the number of wrist and forearm movements among violin players during a typical practice session as well as to evaluate the perception of discomfort and pain felt by the musicians in the past and document how many have been diagnosed with a disorder.

This study has been approved by the Institutional Review Board (IRB), whose contact information is provided on the following page for you to take with you. By signing below, you state that you have read and understood the purpose of this survey and that you consent to participate. This sheet with your signature will be separated from the actual survey to protect your identity. Please keep the following page with the Principal Investigator's and IRB's contact information.

I consent to participate in the survey

I do not consent to participate in the survey

Thank you for Participating!

Demographic Survey

Instructions: Please answer the following questions. We appreciate your answers on all questions, but you may skip any questions you do not wish to answer.

1. Gender: _____ Male _____ Female

2. Dominant Hand: _____ Right _____ Left

3. Student Classification (mark one): Freshman Sophomore Junior Senior Graduate

4. How many years have you been playing the violin? ___________

5. Do you consider yourself a professional musician? _____Yes ______No

6. How many hours/day do you play your instrument? (Including orchestra rehearsals and gigs) __________hrs/day

7. How often do you experience pain/aches/discomfort in your upper limbs (arms, elbows, hands, and wrists) while or after practicing your instrument?
____Everyday ____3-4 times a week ___1-3 times a week ___Once a month or less

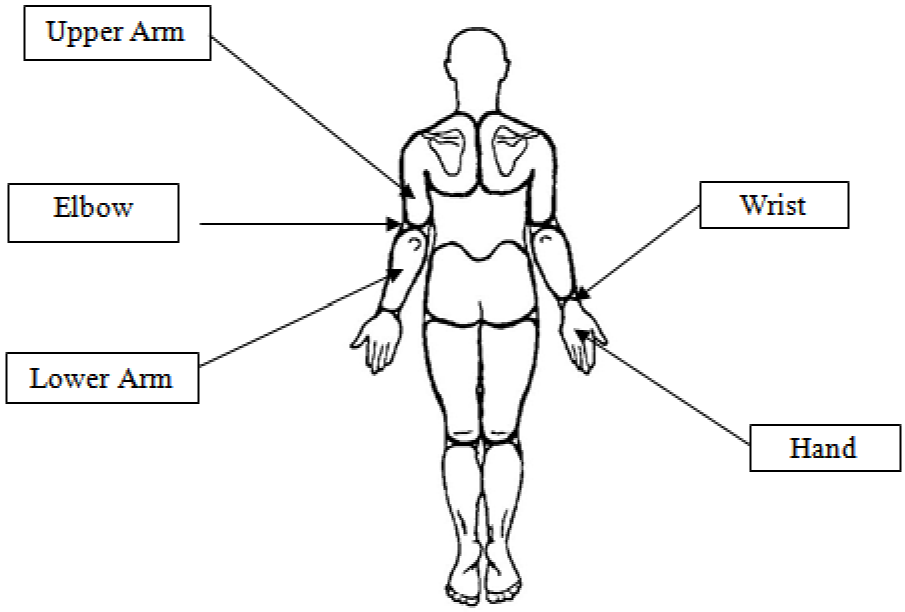
8. Have you ever sought medical help due to musculoskeletal pain in the upper limbs (arms, elbows, hands, and wrists)? _____Yes _____No
(Note: Musculoskeletal pain refers to pain that affects bones, muscles, ligaments, tendons, and nerves. This pain can be localized in a specific area or it can be widespread. Some common musculoskeletal pains include tendonitis, myalgia (muscle pain) and carpal tunnel syndrome.)

9. Have you ever been diagnosed with a musculoskeletal injury to your upper limbs? (i.e. carpal tunnel, tendonitis, focal dystonia, etc..)

____Yes ____No

If Yes, specify the diagnosis: ____________________________________

Discomfort Survey



Have you had Pain, Ache, Discomfort, Injuries in:	In the past 12 months	
	When did it occur	Duration It lasted
Left Upper Arm		
Left Lower Arm		
Left Elbow		
Left Wrist		
Left Hand		
Right Upper Arm		
Right Lower Arm		
Right Elbow		
Right Wrist		
Right Hand		

Would you be willing to participate in a lab experiment? ____Yes ____No

If your answer was Yes, please read the following consent form which provides an overview of the study and the procedures to be implemented.

Study Title: Documenting posture changes and number of repetitions among violin players during a practice session

Performance site: Louisiana State University, Department of Construction Management and Industrial Engineering, Human Factors and Ergonomics Laboratory (Room 3413 Patrick Taylor Hall)

Investigators:

Laura Ikuma, PhD (likuma@lsu.edu) 225-578-5364, 3135A Patrick Taylor Hall

Cristina Handal (chanda2@tigers.lsu.edu)

Purpose of the study: The present research project has the following purposes:

1. Document the changes in posture and number of finger repetitions among violin players during a short (30 min) practice session.
2. Evaluate the perception of discomfort and pain felt by the musicians in the past and document how many have been diagnosed with a disorder.
3. Evaluate the possible relationship between posture and repetition with discomfort.

Subject Inclusion: Violin players who major in violin performance at LSU or music professionals all above the age of 18.

Number of subjects: 30

Study Procedures: You will first read this consent form and be given a verbal explanation of the experiment. If you agree with the terms of participation, you will sign the consent form. You will be shown a body diagram and asked to give a rating from 0-10 depending on the level of pain/discomfort felt on your upper limbs(upper arm, lower arm, elbows, hands, and wrists) at that moment. Following this, the researcher will tape the twin axis electrogoniometers and the torsiometers to your hands and forearms respectively. You will warm up for 15 minutes playing scales of your choice. You will be asked to play a piece that you have been working on for 30 minutes. Data from the movement of your wrists and forearms will be stored on the data logger and later downloaded to a personal computer using the appropriate software. After the 30 minutes have been completed, the researcher will ask you to mark another body diagram identical to the one you filled at the beginning.

Benefits and Compensation: There are no direct benefits or compensation for participation. Yet, the experiment may provide useful information about how posture changes and repetition are associated with pain. This research will help us determine why some musicians experience pain and develop musculoskeletal disorders as a result of playing their instrument.

Risks/Discomfort: There are no risks associated with the experiment. You will mimic a typical practice session and may take breaks whenever you choose during the experiment.

Right to Refuse: At any time during the experiment, you have the right to not participate or withdraw from the study. There will be no penalties for withdrawal.

Privacy: The LSU Institutional Review Board (which oversees university research with human subjects) may inspect and/or copy the study records.

Results from this study may be published, but the information will remain anonymous. Participant identity will remain confidential unless disclosure is legally compelled.

Signatures: The study has been discussed with me and all my questions have been answered. I may direct additional questions regarding study specifics to the investigators. If I have questions about subjects' rights or other concerns, I can contact Laura Ikuma, Construction Management and Industrial Engineering, (225)578-5364 or Robert C. Mathews, Chairman, LSU Institutional Review Board, (225)578-8692, irb@lsu.edu, www.lsu.edu/irb. I agree to participate in the study described above and acknowledge the researchers' obligation to provide me with a copy of this consent form if signed by me.

Subject Signature:____________________________ Date:_________________

Printed Name:__________________________ Email:______________________

APPENDIX C: BODY DISCOMFORT MAP WITH THE BORG-CR10 SCALE

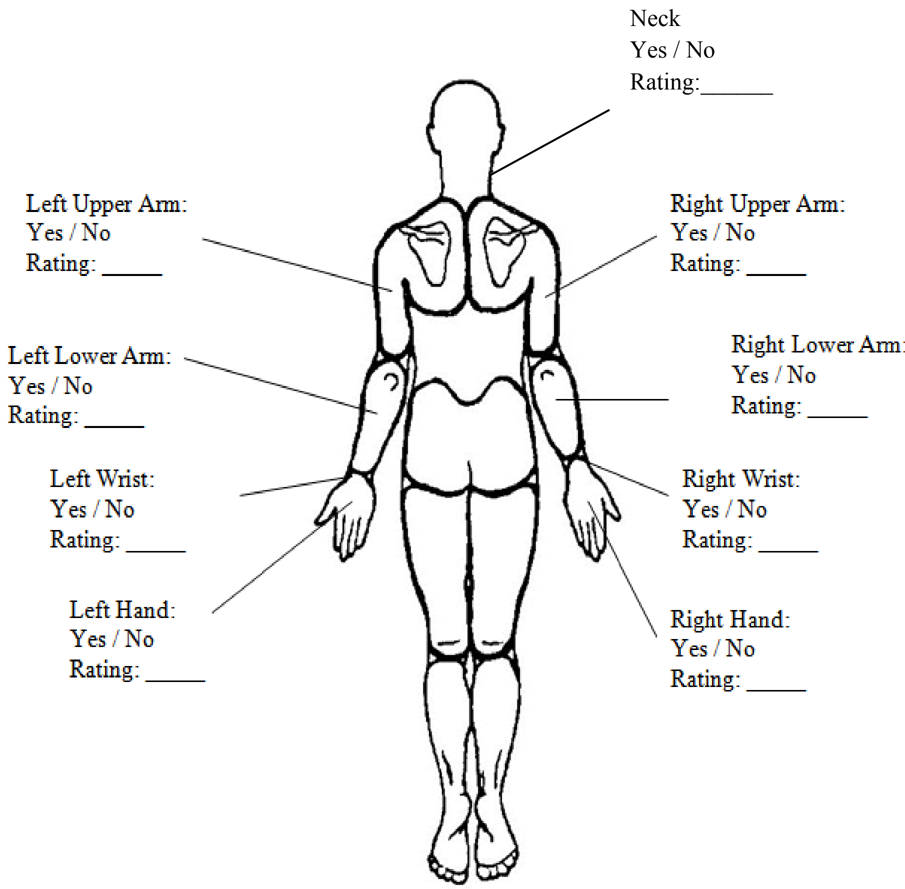
Borg-CR10 Discomfort Rating Scale

0	Nothing at all
0.5	Extremely weak (just noticeable)
1	Very weak
2	Weak (light)
3	Moderate
4	Somewhat strong
5	Strong (heavy)
6	
7	Very strong
8	
9	
10	Extremely strong (almost max)

Body Discomfort Map (BDM)

Discomfort Survey

Please circle Yes or No for each body part to indicate if you are experiencing discomfort currently, and give a rating using the Borg Scale used earlier if you answered Yes.



VITA

Cristina Handal is a native of San Pedro Sula, Honduras where she began her degree in Industrial Engineering. Cristina moved to the United States in the fall of 2006 to complete her undergraduate studies earning two degrees, one in Industrial Engineering and one in Arts in May 2010. That same year she began Graduate school with a Master's of Science in Industrial Engineering under the supervision of Dr. Laura Ikuma. She is currently working full time as a project engineer for Flowserve Corporation in Baton Rouge, Louisiana.