INVESTIGATION INTO THE EFFECTS OF PLAYING POSTURE ON FATIGUE IN VIOLINISTS AND VIOLISTS

by

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Abstract

Playing a musical instrument is a common pastime around the world and for some, it is a career and how they make their living. Musicians' bodies are put under constant stress from playing an instrument. Statistics have suggested that upwards of 80% of professional musicians suffer from a performance-related musculoskeletal disorder (PRMDs) that can lead to the inability to play the instrument for a period of time and therefore affect their ability to work. Musicians are being diagnosed with PRMDs at earlier ages, especially those in schools for music. Violinists and violists form one of the groups that is most likely to experience a PRMD. Most research has concluded that along with overuse injuries, the asymmetrical playing position plays a huge role in injuries experienced by violinists and violists. Past research has found that sitting while playing, a high string musician puts an unbalanced load on the hip bones and musicians feel more pain when sitting. There is limited previous research on the effects of fatigue in violinists and violists, especially how playing posture (i.e., sitting or standing) affects measures of fatigue. The purpose of this study was to investigate the effects of sitting and standing on fatigue in high string musicians in hopes of finding ways to reduce PRMDs in violinists and violists. A very thorough literature review revealed that sitting while playing results in high levels of perceived fatigue in upper string musicians and that a plan of introducing periods of standing could possibly decrease the levels of fatigue the musicians experience. An experimental research study is proposed in order to verify the findings of the literature review.

Keywords: VIOLIN, VIOLA, PRMDS, FATIGUE, SITTING, STANDING, MUSIC, HEALTH, POSTURE, CLASSICAL MUSICIANS

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Introduction

Playing a musical instrument is a very common pastime for people of different ages throughout the world. Musicians are required to develop fine motor skills and perform very complex body movements to achieve the required postures and techniques that accompany playing an instrument. Just like athletes, the strain that is put on the body from playing a musical instrument can lead to many musicians becoming injured (e.g., Kaufman and Ratzon, 2011; Guptill and Golem, 2008; Kok et al., 2018; Zaza, 1992; Steinmetz et al., 2012; Ackermann et al., 2012).

In a study of professional musicians in the Netherlands, it was found that over 60% of the musicians suffered from a musculoskeletal system injury that prevented the musicians from performing for at least some period of time. Most of these injuries occurred from an imbalance of load caused by either playing too much (overuse) or using the wrong technique (misuse). A change of physical 'musical' load or the intensity in which the performer plays is the main way that overuse injuries occur in musicians. These changes in load can come from a change in instrument, teacher, or even practice routines. (Rietveld, 2013)

The term Performance Related Musculoskeletal Disorder (PRMDs) was created to describe the musculoskeletal disorders that musicians experience as a result of playing their instrument (Zaza and Farewell, 1997). The definition states that a PRMD is "pain, weakness, numbness, tingling, or other symptoms that interfere with your ability to play your instrument at the level to which you are accustomed". This definition does not include mild aches and pains. (Zaza and Farewell, 1997; Zaza et al., 1998). It is important to understand the risks and outcomes that are associated with musculoskeletal injuries in musicians. Just as a musculoskeletal disorder causes discomfort and in some cases an inability to perform work-related tasks in an occupational setting, PRMDs can also lead to the loss of function and playing ability for musicians (Zaza, 1998). It is difficult to get a definitive statistic of the length that musicians are our because every injury is different, and every musician handles it differently. It is common in the music industry to ignore the pain whether it be consciously or subconsciously and play through the pain out of fear of losing their job or disruptions in career advancement (Dommerholt, 2009). According to a 2005 Bureau of Labor Statistics report, musicians held roughly 249,000 jobs in 2004. 40% working part-time and almost half being self-employed. (Foxman et al., 2006). This inability to perform in an industry that is already unstable and competitive can drastically hinder a musician’s career, so it is vital to understand more about these injuries so that musicians can not only recover from injuries faster but prevent them in the first place. These injuries can lead to financial hardship for the musicians, and since most work only part-time or are self-employed, they lack the health insurance that is needed to keep them safe and healthy (Foxman et al., 2006). Not only can the loss of playing ability affect the musician financially, but it can often lead to self-doubt and psychological declines due to the disruption of the intimate relationship many musicians describe having with their instrument and loss of their passion (Guptill, 2011).

Injuries in Violinists and Violists

The most commonly affected group of musicians that suffer from musculoskeletal disorders are string musicians. Rietveld (2013) reported that bowed-string instrumentalists and guitarists combined made up 53% of injured musicians with violinists specifically making up 30% of all musicians’ injuries. The violin and viola are very similar instruments, with the viola being slightly bigger. Mechanisms of injury occurrence are similar, but the slightly longer and heavier body of the viola could introduce additional strain compared to the violin. For the sake of this study, violins and violas will be considered equal, but more research could be done to analyze the difference in injury production between the two instruments. It is commonly believed that the asymmetrical playing position that string musicians are forced to hold for long periods of time is what leads to many injuries in the back, neck, and shoulders (Moller et al., 2018). Of the string musicians, violinists and violists are most commonly affected due to the postural mechanism of holding the instrument between the jaw and the shoulder as well as the repetitive movements induced by the bowing arm (Nyman et al., 2007; Filho and da Silva, 2020; Rietveld, 2013; Tubiana et al., 1989). Of all overuse disorders in violinists and violists, 75% occurred in the upper extremity (Rensing et al., 2018). Rensing discussed the implications of both intrinsic and extrinsic factors on the presence of PRMDs in violinists and violists. The intrinsic factors consist of age, size, and underlying diseases that might affect the occurrence of PRMDs. Extrinsic factors, on the other hand, come from the musician's posture, playing technique as well as the environment in which the musician is performing (Rensing et al., 2018). Since extrinsic factors are potentially modifiable, it is of greater interest, and has been the subject of many research studies (e.g., Spahn et al., 2014; Ohlendorf et al., 2018; Levy et al., 1992).

In a study of 29 professional violinists, 15 (51.7%) reported a physical problem that they believed to be caused by playing their instrument. All 15 of those violinists reported at least one problem related to the upper extremity. Generally speaking, the wrists and shoulders were the most affected. Those problems also led to difficulties holding the violin, performing vibrato, shifting, pizzicato, and bow hold, all of which are important aspects of playing the instrument (Hiner et al., 1987). Ackermann conducted a study with 32 skilled violinists to analyze the physical characteristics and pain patterns of the participants. The physical measurements of the violinists were measured by a physiotherapist and then analyzed to create prediction equations. The prediction equations are used to determine a correlation between physical characteristics and pain patterns. Among all the violinists, pain in the upper back was common and was associated with physical dimensions and positioning of the violin. The study found that the only physical dimension that was associated with potential injury risk was in the arm, this was believed to be because of the large gross movements conducted by the right arm while the violinists are playing. Ultimately this study showed the importance of proper set-up with the violinist to prevent possible injury (Ackermann and Adams, 2003).

Besides overuse injuries caused by playing for long periods of time, musicians often suffer injuries from misuse or holding the instrument/body in the wrong position. Ohlendorf et al. studied 13 professional violinists and violists to compare the difference in the musicians' posture and body position between their playing position and habitual seating position. Playing the instrument rotated the body more to the right, increased spine extension, abducted the scapula, and lowered the right shoulder. Their research showed that playing a violin or viola can have significant changes out of the normal body position that can put extra strain on the muscles. (Ohlendorf et al., 2018)

Playing Posture in Violinists and Violists

Violinists and violists have the option to be played sitting or standing. While rehearsing privately many musicians will stand, but then during rehearsal will be required to sit for hours at a time in an elevated arm position and therefore report more neck-shoulder pain than other instruments (Nyman et al., 2007**)**. Since these musicians use these different postures, understanding how these postural differences could affect factors related to fatigue and ultimate injury is important. Spahn et al. (2014) observed the body movements that occurred in violinists and violists while sitting and standing. Posturographic measurements revealed that while standing, weight distribution was fairly evenly distributed between both feet while in the sitting position, the right sitting bone experienced a heavier load. It was believed that the unbalanced sitting position was due to the asymmetrical playing posture required from violinists and violists, decreased mobility in the pelvis, and the limited ability to balance between the two sitting bones. Through analysis, Spahn et al. noticed that in the sitting position, the lower trunk remained nearly motionless while the musician was playing. This means that the back area between flexible and inflexible trunk segments was heavily used. This corresponds with the musculoskeletal pain history of the musicians, almost all of whom reported some sort of pain in their neck and back after an orchestral performance. (Spahn et al., 2014). Other studies have also shown that lower back pain is very common in violinists (Steinmetz et al., 2010). A study conducted by Nusseck and Spahn observed the postural stability and balance of musicians to that of non-musicians. Posturography measurements were taken of musicians of all different instrument groups as well as a non-musician control group all in a standing position. It was observed that 25% of the upper string musicians, along with 23% of pianists, and 33% of guitar players had a weight distribution without the instrument that was significantly shifted left than the control group. The authors suggested that the reason upper string players have a shifted weight distribution is due to the asymmetrical playing position where the violin sits on the left shoulder. The body, therefore, adapts to create a playing position that lets the right hand (bow hand) be freer but without the instrument, the body might still try to maintain the playing position. It is suggested that maintaining a certain posture or playing position can affect the musculoskeletal system and consequently generate postural misalignments. Therefore, the author recommended that training programs should be implemented for music students toward a more stable and balanced posture. (Nusseck and Spahn, 2020)

Sitting vs. Standing in Other Professions

The potential effect that different postures have on the ability to perform a task, or experience discomfort, has been investigated in other professions. Many other professions also experience pain due to prolonged sitting. In a study of office workers on the short-term effects of prolonged sitting, it was found that after just two hours of sitting at a computer, participants experience increased discomfort in the lower back and hip region and even some slight deterioration in creative problem solving was observed (Baker et al., 2018). Although there was no observed change in muscle activity throughout the two hours, the study still suggests that prolonged sitting can have negative short-term effects and recommended breaks to change position. Husemann et al. (2009) took data entry officer workers and split them into two groups to be observed over a week. One group would sit for a majority (~75%) of the day while the other group would spend 50% of the day standing and the other 50% sitting. Questionnaires were collected at the beginning and the end of each day. Across all participants, responses at the beginning of the day were all relatively the same. Both groups reported an increase in complaints at the end of the day, but the sit-stand group reported far fewer complaints than the sitting group. This study shows how implementing a sitting-standing paradigm can decrease reports of musculoskeletal discomfort in the workplace. The same could be said true regarding violinists and violists who should alternate sitting and standing to ease musculoskeletal discomfort. Thorp et al. (2014) also conducted a study of overweight/obese office workers to examine the effects of intermittent standing bouts on musculoskeletal fatigue and discomfort. Participants simulated their everyday occupational tasks during two, 5-day sessions lasting 8 hours each day. The participants were randomly assigned an order to conduct the sessions. In one session, participants would complete their tasks sitting for the 8-hour day. In the other session, participants would alternate every 30 minutes between sitting and standing with the use of a motorized standing desk. In questionnaires provided after each session, participants reported a much higher total fatigue score during the fully sitting session as compared to the sit-stand session. Lower back pain was much lower in the sit-stand session than in the sitting session. There was also a noticeable trend toward overall productivity during the sit-stand session. (Thorp et al., 2014)

Fatigue: What It Is and How to Measure It

Fatigue is a common occurrence for all humans in many aspects of daily life. Despite the common nature of fatigue, scientists and researchers are not in agreement on an exact common definition of fatigue. Fatigue comes in many shapes whether it be physical, mental, or even pathophysiologic (Aaronson et al., 1999). Generally speaking, fatigue is a lack of energy or feeling of exhaustion that ultimately leads to difficulty in completing voluntary tasks or movements (Wan et al., 2017). For this study, physical fatigue which encompasses the decreased ability for a muscle to function properly and the feeling of tiredness felt by the musician will be the focus. There are different ways of measuring fatigue. Subjective measures rely on a person's opinion of what is felt by the body, whereas objective measures rely upon clinical equipment that creates quantitative measures of fatigue. These methods will be discussed in-depth in a later section.

When it comes to creating a more definitive definition of muscle fatigue, two major definitions will be considered because of their involvement with the different ways that physical fatigue can be measured. The first definition states that fatigue includes the overwhelming sense of tiredness, lack of energy, and feeling of exhaustion that ultimately results in the inability to perform voluntary tasks (Wan et al., 2017). This definition of fatigue draws on the idea of subjective fatigue and focuses more on the specific feelings that humans notice when fatigue begins to occur. The other definition states that muscle fatigue can come from a deficit in motor activity, a gradual decrease in force production, or even a decline in mental function that can be measured by a reduction of force produced changes in electromyographic activity, or exhaustion of contractile function (Enoka and Duchatea, 2008). This definition by itself is very vague and covers multiple effects of fatigue that are caused by multiple physiological phenomena, but it includes the measurable effects of fatigue on the body that are useful in quantifying muscle fatigue. Where the definition of fatigue provided by Enoka and Dechatea focuses more on objective or observable measurements, the definition provided by Wan et al. is more focused on subjective or self-reported feelings of fatigue. Subjective and objective measurements of muscle fatigue have their benefits and limitations when it comes to expressing fatigue, but both provide unique insights into the process of fatigue.

Fatigue Mechanisms

Before discussing the different ways to measure fatigue there must a deeper understanding of the mechanism behind muscle fatigue. There is no single cause of muscle fatigue in humans. The idea of the task dependency of muscle fatigue acknowledges that one of the several physiological processes required for contractile proteins in the muscle to generate force has been impaired because of the task being performed (Enoka and Deuchatea, 2008). Metabolic factors such as hydrogen ion, lactate, and inorganic phosphate along with other fatigue reactants can lead to fatigue from a cellular level (Wan et al., 2017). These metabolites can reduce the affinity of Ca^{2+} binding to troponin. Alternatively, the amount of Ca^{2+} released from the sarcoplasmic reticulum can affect the binding to troponin. (Vøllestad, 1997). Since voluntary force production occurs from a sequence of these physiological events, each one of these steps provides a limiting factor for force production by affecting the required sequence of events.

Cross-bridge cycling, the primary mechanism of force production and requires adequate ATP supplies acquired through aerobic and anaerobic metabolic pathways to continue to function (Vøllestad, 1997). The three major ATPases that use ATP during muscle contraction (and relaxation) are Na^{+}/K^{+}-ATPase, myosin ATPase, and Ca^{2+}-ATPase and use 10%, 60%, and 30% of the ATP used, respectively (Wan et al., 2017). If ATP levels are altered, these changes can ultimately lead to decreased force production and therefore induce muscle fatigue. Blood flow and O_2 delivery also play an important role in delivering oxygen necessary for ATP production while disposing of metabolic wastes (Wan et al., 2017). Together, both energy and blood flow provide important functions in muscle contraction and changes to either system can lead to muscle fatigue. Miar et al. (1996) created a model that revelated that as muscles become fatigued, they lose their ability to absorb energy before failure, especially in stages when injuries can be avoided such as the early stretching phase. This makes fatigue an important factor in the occurrence of acute muscle strains since fatigue alters the muscle's ability to function properly. This means that as the muscles of the violinists and violists are fatigued while playing, their risk of experiencing a muscle strain begins to rise.

Subjective Fatigue Measurements

When assessing muscle fatigue in humans, a common result of fatigue is pain. Recent studies have concluded that musculoskeletal pain and fatigue occur due to the same physiological mechanisms so, therefore, pain also plays a role in identifying fatigue in humans (Burnes et al., 2018). Researchers can collect this information through subjective and objective measurements as mentioned before. Subjective measures of fatigue that involve self-reported indications of fatigue can be broken down into a few categories, many of which are present in the Musculoskeletal Pain Intensity and Interference Questionnaire for professional orchestra Musicians (MPIIQN) developed by Patrice Berque, Heather Gray, and Angus McFadyen (Berque et al., 2014). This questionnaire is used to access pain and fatigue in relation to performance-related musculoskeletal disorders. When collecting information about pain and fatigue, it is important to specify the difference between fatigue and pain, because although they are similar and pain can help identify fatigue, they are still fundamentally different results of physiological mechanisms and pain can result from other influences.

The first category of subjective fatigue measurements would be single-dimension assessment fatigue scales that can be visual, verbal, or numerical that involve scales with pictures, words, or numbers that are assigned to fatigue levels (Salaffi et al., 2012). A common example of this would be the Borg scale where subjects rate the level of perceived exertion or fatigue on a scale from 1-10. The audience of the assessment and their abilities is what determines the best marker whether it be with pictures, words, or numbers. Berque et al. found that the use of numerical rating scales (NRS) in the MPIIQM was highly effective in measuring pain intensity as well as collecting epidemiological data (Berque et al., 2014).

The next category would involve location mapping. The typography of pain/fatigue is utilized by providing a diagram of the human body and asking the subject to mark where they feel pain or fatigue. This allows researchers to observe where the fatigue is occurring (Salaffi et al., 2012). The MPIIQM takes advantage of this technique to allow musicians to indicate where exactly the most pain is occurring and emphasize the spot that experiences the most pain (Berque et al, 2014). This part of the assessment could even be changed to focus on fatigue in addition to pain to observe any correlation between areas that experience pain and those that are the most fatigued.

The final category is the use of a multidimensional pain scale. These are surveys or questionnaires that measure several dimensions of pain and fatigue at one time as a way of making connections and truly capture the quality of life at the same time (Salaffi et al., 2012). The MPIIQM as a whole would be considered a multidimensional pain scale made up of single-dimensional assessment scales and location mapping to measure pain in musicians as well as observe the effects on quality of life. Evaluation of the MPIIQM revealed solid validity and reliability in measuring pain intensity in musicians as well as the potential to measure change over time (Berque et al., 2014).

Objective Fatigue Measurements

Where subjective measures of fatigue rely on what a person says, objective measures of fatigue rely on data that can be measured. To objectively measure fatigue, one has to look at the ways the body changes physiologically due to fatigue. Most noticeably, a muscle is said to be fatigued when the maximal force or power output begins to decline, therefore, fatigue can be measured by examining the gradual decline in maximal force over time (Enoka and Duchateau, 2008). High-string instrumentalists are able to conduct maximal voluntary contractions (MVC) before playing the instrument and use submaximal force productions (%MVC) to observe changes in force production over time while playing their instrument (Möller et al., 2018).

Besides measuring the decline in maximal force production, direct measures of fatigue can also be measured through various other changes brought upon fatigue. Power output, the amount of energy produced by a muscle during a maximal contraction, is a very important direct measure of fatigue because it can provide more insight into how the muscle is working since the concentric contractions demand faster rates of ATP regeneration as compared to isometric contractions and therefore provide more information since changes in energy release can affect the output (Vøllestad, 1997). Both measurements of maximal contraction and power output are a result of a series of events and therefore include various inputs along the way, so it is hard to pinpoint the exact spot of the fatigue or how it is occurring. Maximal voluntary contraction and power output are often used as a starting point to examine fatigue as a whole before moving to more precise investigations that can suggest possible sites and mechanisms. For this reason, tetanic force, the force produced by the muscle when electrical stimulation is added (Vøllestad, 1997), and low-frequency fatigue, the disproportionate fall in twitch force during contractions in high-intensity exercise. (Edwards et al. 1997), have been developed to provide more precise data about where and how fatigue is occurring.

Through electrical stimulation, the force of the tetanic contraction of the muscle can be observed to obtain a measure of the capacity of the muscle without limitations of interactions with the central nervous system (Vøllestad, 1997). Comparisons of tetanic force alongside maximum voluntary contraction can estimate central fatigue. Various investigations (Bigland-Ritchie et al., 1986b; Vøllestad et al., 1988; Mengelshoel et al., 1995) using this method of fatigue measurement have concluded that inducing central fatigue can have varying effects on the different muscles in the body and therefore is not a coherent measure of fatigue. The final direct measure of fatigue, low-frequency fatigue, uses twitch forces to provide an estimate of the loss of force capacity in the muscle (Vøllestad, 1997). A major downside of this method is that the recovery time of the twitch force can take hours and even days to fully recover (Jones, 1996). The downsides of these direct measurements often make it hard to directly measure fatigue in an experimental setting. This is where indirect methods of measuring fatigue allow for fatigue to be measured during a specific task, like playing a musical instrument.

Just like direct methods of fatigue, most indirect measures rely on the force and ability of muscles to contract. Endurance time is an indirect measurement that relies on the principle that exhaustion occurs when the muscle is no longer able to sustain contractions at a target force (Vøllestad, 1997). By measuring the time it takes for a muscle to no longer sustain a target force, fatigue can be directly measured. The most common indirect method of measuring fatigue, electromyography (EMG), relies on the physiological responses of fatigue. Electrodes placed on the surface of the skin detect the electrical activity of the muscles below it and with this information, assessments of frequency and amplitude can indicate fatiguing activity. When looking at the output of electrical signals, an increase in amplitude, decrease in median frequency, and increase in low-frequency signals are indicative of fatigue (Allison and Fujiwara, 2002). So, by measuring the electrical activity of the muscles, we can indirectly measure fatigue in a non-invasive way that doesn't impede on most common movements making it an excellent resource in fatigue studies.

Surface EMG is an integral part of not only general fatigue studies but also in many studies looking at the relationship between fatigue and musculoskeletal disorders in musicians. Fifteen professional and university high string musicians were divided into two groups based on if they had a playing-related musculoskeletal disorder or not and asked to play for an hour while EMG was recording. The EMG sensors collected data from 16 various muscles around the body and found that there were significant differences in muscle activity between the two groups suggesting that the groups experience the effects of fatigue differently, whether they have a PRMD or not (Möller et al., 2018). In a similar study, nine professional violinists were asked to perform a 6-second standardized excerpt while surface EMG was measured. Once the data was normalized to compare across participants it was noted that the levels were higher for the left and right trapezius, the right deltoid, and the right biceps in those who expressed having pain suggesting that those with pain used significantly more muscular force than those without pain (Philipson et al., 1990). In a case study of a violinist performing, EMG data revealed an increase in activity for the left trapezius and part of the deltoid (Steinmetz et al., 2012). In these three studies, the trapezius is a major point of interest. This is because the violin is placed in the left clavicular hollow and supported by scapulothoracic positioning controlled by the trapezius to ensure proper resistance against the weight of the arm and the instrument (Tubiana et al., 1989). By supporting the weight of the violin and the arm, the trapezius can experience an increased load that must be maintained as the violin is held up for long periods of time which can lead to increased fatigue over time. This makes sense why the trapezius is the focus of many fatigue studies about musicians, especially when 75% of violinists and violists who suffer from a playing-related musculoskeletal disorder experienced pain in the upper extremities like the shoulder and neck, most of which are caused by overuse (Fry, 1986). Therefore, the trapezius is an important muscle for measuring fatigue in violinists and violists.

Electromyography Research in High String Musician Injuries and Fatigue

Fjellman-Wiklund et al. (2004) conducted a study that had 12 string musicians play a piece of music at two sessions that were 10 weeks apart while measuring trapezius EMG activity. Each musician showed a similar activity pattern between the first and second session indicating that the musicians were able to repeat their muscle pattern, but there were considerable differences in activity between cello, viola, and violin players and even between individual violinists indicating the ability of EMG to evaluate individual differences in performance to benefit in intervention practices. Another study of 10 professional violinists measured EMG activity during one of three randomized experimental conditions and observed those participants who reported no pain develop an increase in upper trapezius activity than those who reported neck-shoulder pain throughout the session (Berque and Gray, 2002). It was also noted that both groups saw an increase in upper trapezius activity from rest to performance and the group that experienced neck and shoulder pain had higher upper trapezius activity than the pain-free group at rest. The decreased upper trapezius activity in the neck-shoulder group during the experimental conditions suggests that synergistic muscles might be used as a strategy to relieve the load on the trapezius and alleviate pain and fatigue in the performer. A study conducted by Palmerud et al. (1995) was able to prove that with biofeedback training, trapezius EMG activity could decrease, and the load was distributed to other synergistic muscles, so the idea that the trapezius can call on synergistic muscles to share the load of playing the violin or viola is a reasonable proposal. McCrary et al. (2016) used EMG to observe muscle activity in musicians as it relates to physical symptoms but found interesting data about the compensatory action of the trapezius when playing the violin. EMG data where the participants had right shoulder pain presented a decrease in upper trapezius muscle activity connected to an increase in activity of other muscles (pectoralis major, biceps brachii, and anterior deltoid), suggesting that the body recruits other muscles to alleviate the strain on the trapezius while playing. This compensatory action was most noticeable in long bowing excerpts.

Subjective vs. Objective Fatigue Measurements

Subjective and objective measures both have their pros and cons, so it is imperative to know how the two measures compare to each other. In a study designed to determine the correlation between the objective measurement of EMG and the subjective measurement of the Borg scale, 50 healthy participants perform an isometric contraction of the back extensors to exhaustion while EMG detected electrical activity and the subjects rated their subjective fatigue using the Borg 10-point scale. Upon analysis, there was a noticeable correlation between the Borg Scale and the EMG data suggesting that subjective and objective measures of fatigue share a strong correlation (Dedering et al., 1999). Chan et al. (2000) used a similar framework, however, specifically applied it to violinists. In their study, EMG was used on fourteen professional violinists to record the muscle activity of the upper trapezius before and after a training session while at the same time the violinists were asked to subjectively describe their fatigue using the Borg Scale. When analyzing the differences in fatigue measurements before and after the session, there was a noticeable increase in fatigue on the self-perceived exertion level while regression analysis revealed that there was not a significant difference between the EMG activity during the training session (Chan et al., 2000). This difference in measurements of fatigue suggests that multiple sources account for violinists' and violists' self-perceived fatigue. This proves a very important distinction that both subjective and objective measures of fatigue can describe the same action of fatiguing, but subjective fatigue must be used cautiously because of the external factors that can influence a performer's self-perceived fatigue.

Conclusion

Playing the violin and the viola puts a lot of strain on the body as seen by the numerous studies showing that high-string instrumentalists are on the most likely groups to get injured as a result of playing their instrument. Most studies point to the asymmetrical playing position and postural differences as the main cause (Rensing et al., 2018; Ohlendorf et al., 2018; Spahn et al., 2014; Edling and Fjellman-Wiklund, 2009). These causes lead to muscle fatigue in violinists and violists. The fatigued muscle is more likely to experience a muscle strain as seen by the studies conducted by Mair et al. (1996) which means that as violinists and violists experience muscle fatigue, they are at higher risk for developing a musculoskeletal disorder. Very few studies have been conducted on fatigue in high string players and those that have been done focus on playing the instrument as a whole and not the effect of playing posture on fatigue (Ohlendorf et al., 2018; Spahn et al, 2014). The research that comes from looking at sitting and standing in violinists and violists reports that weight distribution is more balanced when standing while the force production on the hip bone is unbalanced when sitting. Sitting was also associated with a more static playing position rather than the freedom of movement while playing in the standing position.

These findings align with responses from questionnaires stating that violinists experience more fatigue and pain when sitting for long periods of time as compared to standing. When looking at other professions such as office workers who also report feeling more fatigued when sitting. It is reasonable to assume that sitting results in more fatigued muscles as compared to standing and therefore has the possibility to lead to more injuries in high string instrumentalists. One way of reducing that feeling of fatigue could come from the introduction of periods of standing during rehearsals and practice sessions as studies of office works have shown that alternating sitting and standing results in few complaints of fatigue and pain.

The current research lacks any connections made between sitting and standing on measurable muscle fatigue. Most research comparing sitting and standing examines posture, movement, or subjective measures of fatigue while the current research on musculoskeletal disorders and fatigue doesn’t take into account sitting and standing. Further research needs to be conducted that specifically compares subjective and objective measures of fatigue with sitting and standing in high string musicians. These missing gaps are taken into consideration in the following proposed experimental study.

Proposed Study

The goal of this proposed study is to investigate the effects of sitting and standing on fatigue in violinists and violists. This study was planned to be conducted in Spring 2021 at

Appalachian State University, but due to the health and safety of researchers and participants during the Covid-19 pandemic, it was decided to postpone laboratory procedures. This plan was designed with the resources and personnel available in the Beaver College of Health Sciences and Hayes School of Music at Appalachian State University but may be adjusted to fit other investigators and their institution's research.

The study begins with the collection of violinists and violists to be the subject of the research. A population of 20 participants was decided for this study to assure a large enough pool to collect data but was also based on predicted participant availability at the Hayes School of Music where musicians would be contacted. Participants would undergo a screening test (Appendix 1.1) to ensure that all individuals are at least 18 years of age, have played the violin or viola for at least a year, and there are no musculoskeletal or medical injuries present that prevent the participant from playing the violin for an hour. Participants, who passed the screening test would be brought to the Biomechanics Lab in Leon Levine Health Sciences Building to conduct the study. The study is conducted over two days in the laboratory separated by at least 72 hours to ensure that the first session does not have any effect on the second session.

On the first day that a participant arrives at the laboratory, the participant will undergo informed consent to ensure that the participants understand what they will be asked to complete during the study and to ask any questions. The participant will then complete a questionnaire (Appendix 1.2) to collect information about musculoskeletal injuries the musician has had in the past as well as if the musician has had any issues with fatigue or pain while playing their instrument. The questionnaire is based on the Musculoskeletal Pain Intensity and Interference Questionnaire for Professional Orchestra Musicians (MPIIQM) with a few changes to accommodate questions regarding fatigue. This questionnaire will be used because of its relevance to orchestra musicians specifically as well as its validity and reliability in providing relevant information regarding musculoskeletal injuries. Upon completing the questionnaire, participants will complete a pre-survey pain and fatigue survey (Appendix 1.3) to provide baseline subjective measures of fatigue that will be used to assess fatigue after each session.

The participants will be randomly assigned a playing position based on the order that they visit the lab and will then perform the opposite playing position during the next session. The musicians will be asked to perform a short excerpt from Kreisler's Praeludium and Allegro (Kreisler, 1905) on their respective instruments while baseline muscle activity will be measured using electromyography (EMG). This excerpt was chosen based on its use in other studies as well as the fact that it covers the entire range of the instrument to allow for an average representation of the movements associated with playing the violin or viola. Four EMG electrodes will be placed on the participant, 2 on the left and right upper trapezius and 2 on the left and right erector spinae. The upper trapezius was chosen because it is often the location where many upper string players report problems as well as that focus of many EMG studies conducted on violinist in the past, so it is known that fatigue is shown in the trapezius. The erector spinae were chosen because of their very important role in sitting and standing which have also been shown to be fatigued and painful in office workers that sit for long periods of time. Therefore, it is suspected that this muscle can be used to show differences in fatigue as high-string musicians sit and stand. The electrode for the upper trapezius muscles should be placed on the midpoint of the line between the acromion and the C7 vertebrae while the erector spinae sensors should be placed two finger widths laterally from the spinous process of the L4 vertebrae. The locations for the electrodes were designated based on recommendations from the Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM) project with the L4 location chosen for the erector spinae chosen due to the ability to find L4 easier than L1 to ensure EMG locations are as uniform as possible across participants.

The participants will then practice for one hour in their assigned playing position before repeating the excerpt again while EMG is measured to observe the change in muscle activity. Once unhooked from the EMG sensors, the participants will be asked to complete the post-session pain and fatigue survey (Appendix 1.4) that will be used to analyze the change in subjective fatigue after playing their instrument. The process will then be repeated at least 72 hours after the first encounter except the playing position will be switched (e.g., participant sits the first time and stands the second time). The EMG data for both the sitting and standing positions will be analyzed to observe any trends in muscle activity such as increasing amplitude or decreasing frequency that would be indicative of muscle fatigue.

Based on the current research, it predicted that an observable increase in the magnitude of EMG data would be seen when comparing the end data to the beginning data regardless of playing position, which shows fatigue just from the act of playing the instrument. It is also suspected that the change in EMG amplitude will be greater in the seated position than in the standing position because of the decreased range of motion and static body position that sitting creates. This correlates with the many studies that show that sitting for long periods of time results in the feeling of fatigue much more than sitting down in both high string players and other occupations.

An increase in rating of perceived exertion or fatigue is expected from the beginning to the end of the session, regardless of playing positions, due to increased muscle activity. However, it is also expected that the ratings of fatigue increase by a greater percentage because of an increase in muscle fatigue believed to be from a reduced range of motion. With the rating of perceived exertion data, subjective perceived exertion measures can be connected with the muscle activity data to determine if the muscle activity corresponds with the exertion that the participants feel. A big possibility that could occur is that the EMG data could show no change in activity from beginning to end while perceived exertion could increase. Some studies have found that subjective measures of fatigue can also include outside influences not just from the muscle activity and would therefore reinforce the idea that fatigue is a complex physiological condition. Although there might not be a way to specifically decrease objective measures of fatigue, if participants report lower ratings of subjective fatigue while standing, it suggests that introducing bouts of standing would still be better in at least reducing perceived fatigue. It is of course possible that the data that is actually collected in the lab may not follow what is believed to occur, but any information obtained from the data will add to the knowledge of how sitting and standing affect muscle fatigue in violinists and violists.

It is the hope of the researcher that the results from this study will be useful for music education and performing professionals to build rehearsal and personal practice sessions that reduce the muscle fatigue that musicians feel to prevent possible PRMDs. By understanding how sitting and standing influence muscle fatigue and therefore muscle injuries musicians are able to adapt and stay healthy while playing the violin or viola.

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Appendix 1

1.1 Participation Criteria Form

Participation Criteria Form

Investigation into the Effects of Sitting and Standing on Fatigue in Violinists and Violists

Name: ________________________________ Date: ___________

Are you at least 18 years of age?

Yes No

Have you played the violin or viola for at least a year?

Yes No

Are you able to play your instrument either sitting or standing for an hour?

Yes No

Have you had any recent health problems that prohibit you from playing your instrument for an hour?

Yes No

Do you have any known allergies to medical grade adhesives or isopropyl alcohol?

Yes No

1.2 Musculoskeletal Pain Intensity and Interference Questionnaire for Violinists and Violists

ID #: _______

Musculoskeletal Pain Intensity and Interference Questionnaire for Violinists and Violists

Please answer the following questions as truthfully as possible

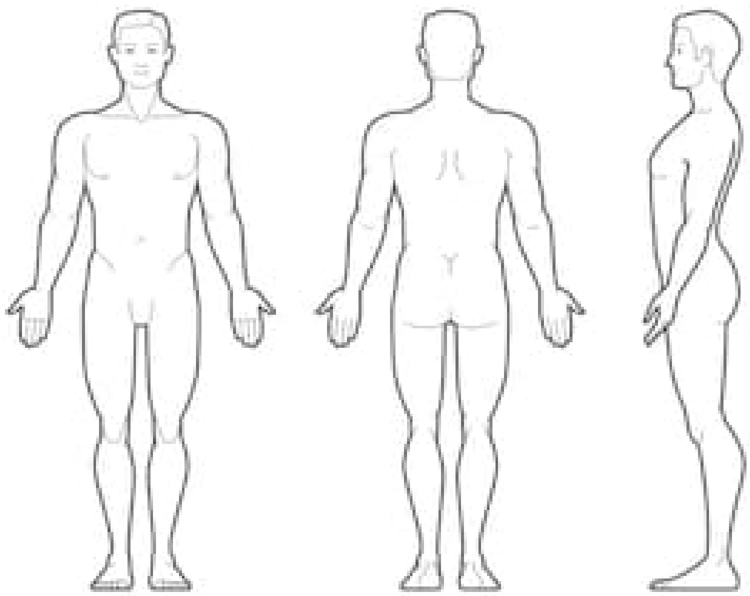
1. What is your age? ____________ **years**
2. Gender (circle one): **Male** **Female** **Prefer not to respond**
3. What is your primary instrument? ____________________
4. What instrument will you be participating in the study on? **Violin** **Viola**
5. Are you currently, or very recently, participating in an orchestra: **Yes** **No**
6. For how many years have you played your instrument? _____________ **years**
7. For how many years have you played in an orchestra? _____________ **years**
8. On average, how many hours per week do you spend playing your instrument **in the orchestra** (this includes rehearsals, performances, recordings)? ______________ **hours per week**
9. On average, how many hours per week do you spend playing your instrument **outside** orchestra duties (this includes individual practice, chamber music, solo performances, demonstration when teaching, gigs, other) ______________ **hours per week**

Playing-related musculoskeletal problems are defined as "pain, weakness, numbness, tingling, or other symptoms that interfere with your ability to play your instrument at the level to which you are accustomed". This definition <u>does not include</u> mild transient aches and pains

10. Have you **ever** had pain/problems that have interfered with your ability to play your instrument at the level to which you are accustomed? **Yes** **No**
11. Have you had pain/problems that have interfered with your ability to play your instrument at the level to which you are accustomed **during the last 12 months**? **Yes** **No**
12. Have you had pain/problems that have interfered with your ability to play your instrument at the level to which you are accustomed during the **last month (4 weeks)**? **Yes** **No**
13. **Currently (in the past 7 days)**, do you have pain/problems that interfere with your ability to play your instrument at the level to which you are accustomed? **Yes** **No**

If your answer to questions 12 and/or 13 is YES, pleas continue. Otherwise stop here, and hand your survey back in.

14. On the body chart, SHADE IN **each** of the areas where you experience **pain/problems**. **Put an X** on the **ONE area** that HURTS the most.



The next four questions relate ONLY to PAIN. Please answer with reference to the ONE area that you marked with an X on the body chart. Otherwise go to Question 19.

15. Please rate your pain by circling the one number that best describes your pain at its **worst** in the last week.

0	1	2	3	4	5	6	7	8	9	10
No pain					**Moderate pain**					**Worst possible pain**

16. Please rate your pain by circling the one number that best describes your pain at its **least** in the last week.

0	1	2	3	4	5	6	7	8	9	10
No pain					**Moderate pain**					**Worst possible pain**

17. Please rate your pain by circling the one number that best describes your pain on **average** in the last week.

0	1	2	3	4	5	6	7	8	9	10
No pain					**Moderate pain**					**Worst possible pain**

18. Please rate your pain by circling the one number that tells how much pain you have **right now**.

0	1	2	3	4	5	6	7	8	9	10
No pain					**Moderate pain**					**Worst possible pain**

The remainder of the survey relates to both PAIN and/or PROBLEMS.

For each of the following, circle the one number that describe how, during the past week, **pain/problems have interfered** with your:

19. **Mood**

0	1	2	3	4	5	6	7	8	9	10
Does not interfere										Completely interferes

20. **Enjoyment of life**

0	1	2	3	4	5	6	7	8	9	10
Does not interfere										Completely interferes

For each of the following, during the past week, as a result of your **pain/problems**, did you have any **difficulty** (please circle ONE number):

21. Using your usual technique for playing your instrument?

0	1	2	3	4	5	6	7	8	9	10
No difficulty										Unable

22. Playing your musical instrument because of your symptoms?

0	1	2	3	4	5	6	7	8	9	10
No difficulty										Unable

23. Playing your musical instrument as well as you would like?

0	1	2	3	4	5	6	7	8	9	10
No difficulty										Unable

Thank you for your participation. Please hand your survey back in.

1.3 Pre-Session Pain and Fatigue Survey

ID #: _______

Pre-Session Pain and Fatigue Survey

1. What position will you be playing in today? **Sitting** **Standing**

2. On the scale below, please circle the one number that corresponds the with level of **exertion** (how tired you feel) for your body as a **whole** right now.

   0 1 2 3 4 5 6 7 8 9 10

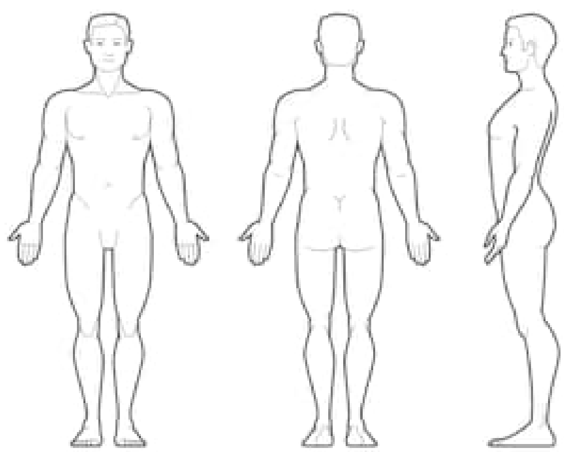
   Not tired A little tired Tired Really tired Very, very tired

3. On the scale below, please circle the one number that corresponds with the level of **pain** for your body as a whole right now.

   0 1 2 3 4 5 6 7 8 9 10

   No pain. A little pain Moderate Severe Worst pain possible

4. On the body chart below please shade in **each** area where you experience **pain/problems** and **put an X** on the **ONE area** that HURTS the most as of right now. **Circle** the area that feels the most tired.



1. On the scale below, please circle the one number that corresponds the with level of **exertion** (how tired you feel) for the area you **circled** right now.

   0 1 2 3 4 5 6 7 8 9 10

   Not tired A little tired Tired Really tired Very, very tired

2. On the scale below, please circle the one number that corresponds with the level of **pain** for the area you marked with an X right now.

   0 1 2 3 4 5 6 7 8 9 10

   No pain. A little pain Moderate Severe Worst pain possible

Thank you for your participation. Please hand in your survey.

1.4 Post-Session Pain and Fatigue Survey

ID #: ________

Post-Session Pain and Fatigue Survey

1. What position did you play in today? **Sitting** **Standing**

2. On the scale below, please circle the one number that corresponds the with level of **exertion** (how tired you feel) for your body as a **whole** after playing your instrument.

   0 1 2 3 4 5 6 7 8 9 10

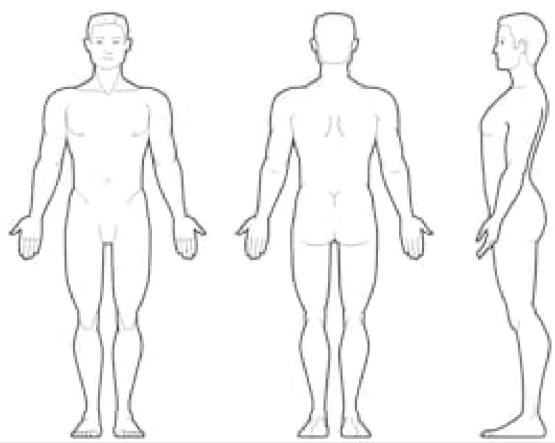
   Not tired — A little tired — Tired — Really tired — Very, very tired

3. On the scale below, please circle the one number that corresponds with the level of **pain** for your body as a whole after playing your instrument.

   0 1 2 3 4 5 6 7 8 9 10

   No pain. — A little pain — Moderate — Severe — Worst pain possible

4. On the body chart below please shade in **each** area where you experience **pain/problems** and **put an X** on the **ONE area** that HURTS the most after playing your instrument. **Circle** the area that feels the most tired.



1. On the scale below, please circle the one number that corresponds the with level of **exertion** (how tired you feel) for the area you **circled** after playing your instrument.

   0 1 2 3 4 5 6 7 8 9 10

   Not tired — A little tired — Tired — Really tired — Very, very tired

2. On the scale below, please circle the one number that corresponds with the level of **pain** for the area you marked with an X after playing your instrument.

   0 1 2 3 4 5 6 7 8 9 10

   No pain. — A little pain — Moderate — Severe — Worst pain possible

Thank you for your participation. Please hand in your survey.