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Electromyography (EMG) Biofeedback Training in Music Performance: Preventing and Reducing Musculoskeletal Pain in Musicians

Carolyn Yarbrough
Scripps College

Electromyography (EMG) biofeedback training in music performance: preventing and reducing musculoskeletal pain in musicians

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By

Carolyn Yarbrough

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Abstract

Musicians are a high-risk occupational group for musculoskeletal disorders. Often manifesting in muscle tension, pain and paresthesia, musculoskeletal disorders can drastically affect comfort, mentality and endurance while performing. This study sought to examine the effects of electromyography (EMG) biofeedback training in reducing musculoskeletal symptoms in music performance. The subjects were university-level violinists and cellists. Over a period of 2-4 weeks, all participants underwent EMG biofeedback training while performing their instrument using audio feedback. No significant results were found, but patterns of decreased muscle tension and increased performance comfort and endurance were observed.

Introduction

In 2009, musculoskeletal disorders accounted for 28% of all workplace injuries that required time off from work, with sprains, strains and tears remaining the dominant type of occupational injury (Bureau of Labor Statistics, 2010). Musculoskeletal disorder is characterized as a condition in which muscles, tendons, joints, ligaments and nerves suffer an injury. The injury can result from a single incident, such as a trauma, or can develop over time. In the latter case, the initial injury is generally minimal if even noticeable, but is exacerbated over time by repetitive use. Work-related musculoskeletal disorders (WRMSDs) tend to be associated with careers that require repetitive and forceful motions, asymmetrical or improper postural positions, poor ergonomics at the work place as well as several psychosocial factors such as stress (Peper et al., 2004). Occupational groups that are characterized by such demands and thus have high incidence rates in musculoskeletal disorder include, but are not limited to, office or computer workers, manufacturers, agriculture workers (Faucett et al., 2002) and musicians (Heinan, 2008).

Musicians comprise a competitive, occupational group that requires intense physical conditioning and preparation. Musicians practice the same, repetitive, forceful motions for hours on end, often "playing through the pain" (Heinan, 2008). Many instruments require extremely controlled movements as well as awkward and asymmetrical postures (Fjellman-Wiklund et al., 2003). Given the demanding and competitive nature of the profession, musicians can develop various musculoskeletal disorders. Such ailments in specific muscle groups appear to be responsible for limiting performance skills (Cutietta, 1986). In a national survey (as cited in Heinan, 2008), 76% of orchestral musicians had to take time off from performing due to injury.

Debilitating, activity limiting and currently one of the most common conditions treated by physical therapists, musculoskeletal pain is often characterized by loss of function and restricted range of motion (Andersen et al., 2011). Musculoskeletal disorders can range from muscle pain and tension to numbness and tingling in the extremities. For the majority of all occupational groups, WRMSDs most commonly occur in the upper extremities, back, neck and shoulders. Among musicians, string players in particular are among the “greater risk” instrumentalists, frequently experiencing neck, shoulder and upper extremity disorders (Fjellman-Wiklund et al., 2003). Due to high incidence rates and the incapacitating nature, musculoskeletal disorders are quickly becoming a main concern within the workplace.

The two central issues for mitigating the problem of WRMSDs are diagnosis and treatment. The determination of what disorders should be considered WRMSDs is the first issue of diagnosis and classification (Van Eerd et al. 2003). Although WRMSDs are widely accepted to be disorders of the muscles, tendons and nerves that are aggravated by work, such musculoskeletal disorders may not be “work-related” but still have identical pathophysiology (Van Eerd et al., 2003). Such indistinct boundaries also lie within the classification of WRMSDs. The majority of WRMSDs that are diagnosed fall under the category of repetitive strain injuries, but the term repetitive strain injury (RSI) is controversial. RSI is considered an “umbrella term” for disorders that result from repetitive motions and thus various other terms have been suggested including cumulative-trauma disorders, occupational overuse syndrome, upper extremity musculoskeletal disorder and others (van Tulder et al., 2007). Presently, however, RSI is the term for any musculoskeletal disorder that result from repetitive motions and can include non-specific strains and specific disorders such as carpal tunnel syndrome, epicondylitis (Gerard et al., 2002) as well as thoracic outlet syndrome, tendonitis and many others (Peper et al., 2004). Many different treatments are available for such disorders and injuries, but as Van Eerd et al. (2003) demonstrates in their review of classification systems, there is a lack of agreement in the types of conditions included as well as the criteria that needs to be met for each, which makes the process of diagnosis, and thus treatment, very challenging.

Specific diagnoses are attempted through analysis of patient history, clinical examination and, more recently, imaging techniques such as magnetic resonance imaging (MRI) and ultrasonography (van Tulder et al., 2007). Often, however, specific diagnoses still cannot be established and due to the "non-specific" nature of the presenting symptoms, such conditions prove to be even more difficult to treat (Peper et al., 2004). Despite the complications that are encountered in determining a specific diagnosis, many disorders can be treated if the advantages, disadvantages, short-term and long-term effects of the available interventions are known. Unfortunately, the major shortcomings in the path to recovery are the lack of substantial evidence indicating any benefits or successes of any one treatment.

In their 2007 study, van Tulder et al. analyzed a number of RSI conditions and symptoms and what treatment options were available and potentially beneficial based on previous studies. For non-specific symptoms, common interventions included exercise therapy, manual therapy, behavioral therapy, biofeedback, massage and ergonomics, but they found that only exercise was deemed "beneficial" while the others were "unknown". For more specific RSIs, such as carpal tunnel syndrome or lateral epicondylitis, interventions included those previously mentioned for "non-specific", but the only known "beneficial" treatments were drugs such as corticosteroids or anti-inflammatory drugs and were only proven so for short-term.

Short-term vs. long-term effects of musculoskeletal disorder interventions have proven to be one of the biggest puzzles in the research. The effectiveness of physical exercise in managing chronic musculoskeletal pain has been supported by many studies over the years (Andersen et al., 2011). However, Little et al. (2008) noted that while various exercise interventions proved to be beneficial in the short-term for recurrent or chronic pain, few have been shown to have substantial benefit in the long-term. Exercise allows for increased muscle strength, but without understanding underlying muscular mechanisms of the problem muscle groups involved in the activities and in the fixed postural habits, the positive effects of exercise likely will not benefit the individual in the long-term (Ma et al., 2011). At the individual level, lack of awareness of muscle tension and overexertion and lack of control of physiological arousal has been indicated to greatly contribute to RSIs (Peper et al., 2004). In musicians, additional risk factors that are connected with musculoskeletal disorders can range from excessive force and improper technique to performance anxiety (Heinan, 2008). Such ingrained and long-standing habits of the individual are crucial to understanding the injury and realizing the importance of long-term effects of interventions.

Recent studies have begun to focus on comparing various interventions and analyzing the long-term and short-term effects of each. In 2008, Little et al. compared the effects of exercise, massage, and the utilization of Alexander Technique on chronic or recurrent back pain. The participants were randomly distributed to control, therapeutic massage, six Alexander technique lessons and 24 Alexander Technique lessons groups, with and without exercise, totaling eight groups. At one year, the groups with six Alexander technique lessons and exercise and 24 Alexander Technique lessons alone, maintained long-term benefits. As they described, the Alexander Technique allows individuals to develop lifelong skills and self-care and allowing them to recognize, understand and avoid poor postural and neuromuscular coordination habits.

Similar claims have been made concerning biofeedback training. In their 2011 study comparing biofeedback, active exercise and passive treatment interventions, Ma et al. examined the effects of the interventions on participants experiencing computer, work-related, chronic shoulder and neck pain. At six months, the electromyography (EMG) biofeedback group maintained the most improvement. In another study, researchers sought to examine the effects of five different approaches employing EMG biofeedback on deep muscle relaxation and stress management and found that all groups with biofeedback training showed decreased muscle tension when compared to the control group (Reynolds, 1984). Sometimes referred to as Muscle Learning Therapy, such biofeedback training employs operant conditioning as an individual uses the EMG feedback – most often audio or visual – to adjust muscular tension or posture (Faucett et al., 2002).

The applications of biofeedback in research and treatment, while not extensive in number, are very wide-ranging. Diagnostically, EMG biofeedback has been used as an electrodiagnostic test in determining musculoskeletal disorders (van Tulder et al., 2007; Heinan, 2008; Sanders et al., 2007) as well as in locating myofascial trigger points – hyperirritable knots in skeletal muscle – and tension-type headaches (Bendtsen, Fernández-de-la Peñas, 2011). As a treatment, biofeedback training has also been studied for use in managing psychosocial factors such as stress and anxiety (Reynolds, 1984; Nagel et al., 1989; Peper et al., 2004), musculoskeletal disorders (Ma et al., 2011; Faucett et al., 2002) and even Parkinson's disease (Mirelman et al., 2011). EMG biofeedback training has probably been most expansively tested in high-risk occupational groups, which includes computer, work-related groups (Faucett et al., 2002; Gerard et al., 2002; Peper et al., 2004; Ma et al., 2011) and musician groups (LeVine, Irvine, 1984; Cutietta, 1986; Fjellman-Wiklund et al., 2004).

As previously mentioned, musicians are among the higher-risk occupational groups for WRMSDs due to the high stress and competitive nature as well as the forceful, repetitive and awkward motions that are required. The combination of these factors also likely increase musicians risk for poor postural and muscle tension habits. With this in mind, musicians do in fact seem to be prime candidates for EMG biofeedback training and treatment, especially when one takes into account the previous few, but successful, studies of EMG biofeedback training in music (LeVine, Irvine, 1984; Cutietta, 1986; Fjellman-Wiklund et al., 2004).

In what is most likely the first study of its kind, LeVine and Irvine (1984) applied EMG biofeedback as a pedagogical tool to examine the effects on left-hand tension in violinists and violists. All of their subjects reported left-hand tension that they felt hindered their performance and worsened with performance anxiety. During the biofeedback session, all subjects had electrodes attached to their left hand and were given feedback in the form of audio “clicks” while playing a difficult passage. Seven out of the nine subjects reported decreased muscle tension and no new symptoms and indicated that they had a better voluntary control of their body.

In a following study, Cutietta (1986) investigated the effects of biofeedback training on music students when playing music passages that focused on more than one psychomotor skill. His study included three violinists, two vocalists, a saxophonist and a percussionist, all of whom were described as having reached a performance plateau with a particular piece. EMG electrodes were placed on the left forearm flexor group in all musicians except for the vocalists who had the electrodes placed on their trapezius. All participants received audio "beeps" as feedback. With the exception of the percussionist, all participants showed significant reduction in muscle tension compared to the non-treatment group ($p<0.05$), with the vocalists showing the most improvement.

These two studies indicate that audio EMG feedback is very effective in music performance training or treatment. In LeVine and Irvine's 1984 study, 89% of the subjects had reduced left forearm muscle tension immediately after treatment and 78% had no relapse at follow-up and in Cutietta's 1986 study, approximately 86% of the subjects had reduced EMG levels at the time of the post-test. Many of the musicians also indicated that they felt more relaxed and aware of their body, post-training. Their music instructors, who were also interviewed after the training, observed improvement in the performances of the participants (LeVine, Irvine, 1984; Cutietta, 1986).

For studies such as these, something to consider more in depth may be the placement of electrodes. Notably in the previously mentioned studies, the purpose was to investigate the general use of biofeedback in music pedagogy and there was little individual analysis done on the participants prior to training to determine symptoms. The minimal criteria in the LeVine, Irvine (1984) and Cutietta (1986) studies was presentation of left hand or forearm tension and having reached a performance "plateau", respectively. In both studies, with the exception of vocalists, all participants had electrodes placed on the left forearm muscles. However, when the purpose of research shifts slightly to focus on music pedagogy and disorder treatment, the criteria for muscle placement must be specified. But, the musculoskeletal system is a complex, intricate system. Different disorders can often present with identical pathophysiology despite the cause being located quite distally from the symptoms (van Tulder et al., 2007). For example, in individuals with thoracic outlet syndrome, symptoms often include pain, paresthesia or weakness in the hand and arm muscles, but the actual cause is the "compression of the neurovascular bundle by various structures in the area just above the first rib and behind the clavicle" (Sanders et al., 2007). Such implications warrant more careful investigation into electrode placement in biofeedback training for musicians.

In string players, the trapezius has been shown to be the most vulnerable of the neck and shoulder muscles to tension and pain (as cited in Fjellman-Wiklund et al., 2004). In their study analyzing EMG trapezius muscle activity in string players, Fjellman-Wiklund et al. (2004) placed electrodes bilaterally across the upper trapezius of nine violinists, two violists and one cellist. They found that all instrumentalists showed almost no "gap levels" – time periods when there is no trapezius muscle activity – while playing, indicating it is difficult to relax completely when playing, and that while the cellist had less static work of both shoulders than the violinists and violists, the cellist had a significantly higher load (voluntary activity). These findings indicate that the dynamic loading of the upper trapezius muscles in string players, and particularly cellists, are a likely source of tension and potentially contribute or lead to work-related neck and shoulder disorders, some of which (e.g. thoracic outlet syndrome) manifest in distal symptoms.

This study sought to test the hypothesis that the use of EMG biofeedback training in music performance can reduce trapezius muscle tension and can thereby be effective in preventing and reducing musculoskeletal symptoms characteristic of WRMSDs.

Materials and Methods

Subjects

Participants included five university-level string musicians, two violinists and three cellists, one of which was the principal investigator. Participants were members of the orchestra at Scripps College and were recruited through word of mouth. All participants exhibited symptoms of pain, tension, discomfort and/or paresthesia while performing and when interviewed expressed that they felt these symptoms interfered with their performance. None of the participants were seeking outside treatment or had had previous biofeedback training.

Equipment

Electromyography (EMG) measures of subject upper trapezius muscles were collected using AD Instruments equipment and the program LabChart7. AD Instruments equipment used included a PowerLab 26T, disposable surface electrodes and Bio Amp cables. Audio was produced using Event Manager in LabChart and an external speaker.

Procedure

The study consisted of a base-test, 3-8 biofeedback sessions and a post-test for each participant (Fig. 1). The base-test was done without using audio feedback in order to acquire accurate baseline trapezius EMG readings. The baseline test consisted of two separate music items played by each participant. The first was a scale in which they felt no symptoms and felt relaxed while playing. The second was a piece in which they experienced their symptoms. This allowed for baseline comparison of EMG readings for a subject performing relaxed with no symptoms and tense with symptoms, and for determination of what the initial threshold should be set at for each individual. A threshold was designated as a point at which an EMG signal spiked above a voltage that was higher than the signal seen in the "relaxed" scale. This threshold became the "event" in LabChart Event Manager at which a warning tone would be elicited during the biofeedback sessions. A "beginning of study" questionnaire was given in which they were asked about their level of music experience and to evaluate their performance mentality and their level of pain or discomfort on a scale of 1 to 5, with 1 designating nonexistent and 5 designating severe.

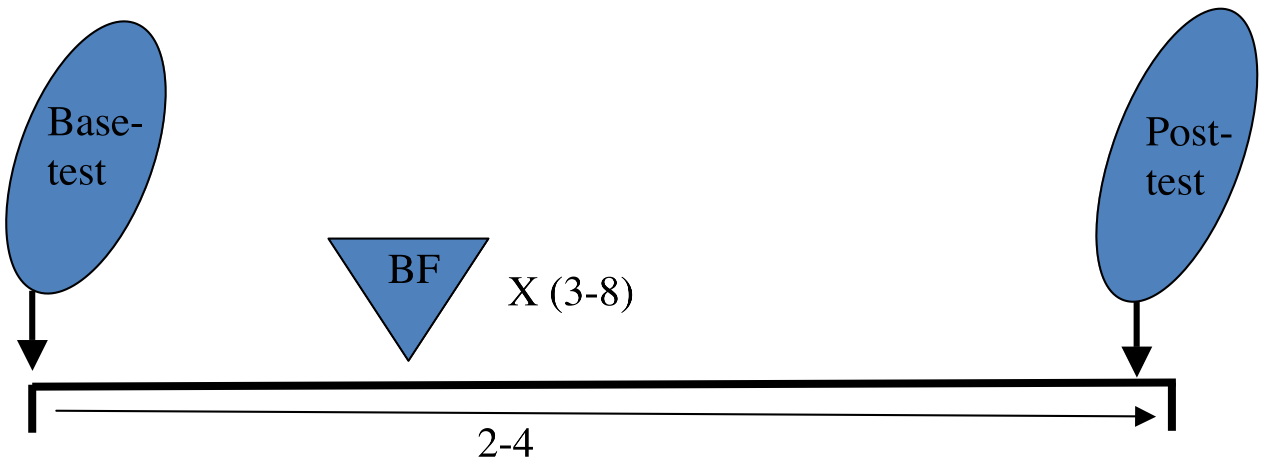

Figure 1. Study Timeline (BF= biofeedback sessions with audio feedback, lasting approximately 30 minutes)

Immediately following the baseline, all participants were given a pre-testing training session in which they had a chance to get accustomed with the equipment. All participants sat with the electrodes placed bilaterally across the upper trapezius in line with the seventh cervical vertebrae (C7) and a ground electrode placed on the ankle. Participants were instructed to move their arms and tense different muscles to see how the signal changed in response to their movements and to hear the warning tone that was given at a certain threshold. Audio feedback was chosen over visual feedback because previous studies with musicians also used audio feedback (LeVine, Irvine, 1984; Cutietta, 1986) and in this study musicians were required to read music during the biofeedback sessions.

Training sessions were scheduled over a period of 2-4 weeks at each participant's convenience. In all of the training sessions, the individuals played one piece in which they experienced their symptoms, but a piece that was different from the one they played in the baseline test. With the electrodes placed bilaterally across the upper trapezius, the participants were instructed to play the piece until they heard the warning tone – the subjects only heard the warning tone, they could not see the EMG in real time. Once they heard the warning tone, they had to stop playing and start over. This design was based on the hypothesis that tension builds up gradually. A musician is likely not aware of the rising tension until it manifests in pain or discomfort, so the sessions are designed to train the musician to stay relaxed as long as possible. Also, taking brief pauses in activity have been shown to have positive effects, reducing WRMSD discomfort (Faucett et al., 2002; Peper et al., 2004), so each individual was instructed to take a short break, lasting approximately 30-60 seconds, to allow for the muscles to relax again. During these breaks the investigator asked each subject about their experience. Thresholds were adjusted throughout the training period if the subject successfully managed to make it through the entire piece without setting off the threshold tone.

The post-test was identical to the procedures of the base-test and the piece performed was the same as the baseline, not the training sessions. At the end of the training period, subjects were given an "end of study" questionnaire in which they were asked to rate their symptoms on a scale of 1 to 5, with 1 designating nonexistent and 5 designating severe, and about their performance mentality and personal experience with biofeedback. Initially this study was designed so that there would be a one-month follow-up test, but due to time constraints and subject scheduling difficulties, this last test of the study was unable to be carried out.

Statistical Analysis

Paired t-tests were used to compare EMG data between the base-test and post-test for each individual and two-way analysis of variance (ANOVA) tests were used to compare EMG data between the subjects. The parameters analyzed included the number of times the subject exceeded the set EMG threshold, the length of time the subject remained above the threshold and the length of time between each threshold period (Fig. 2). If the subject managed to reduce tension and required adjusted thresholds, the final threshold they were trained with was used in statistical analysis, using that final threshold to calculate and analyze the EMG signal at the base-test and post-test. All significant values were reported at $p < 0.05$.

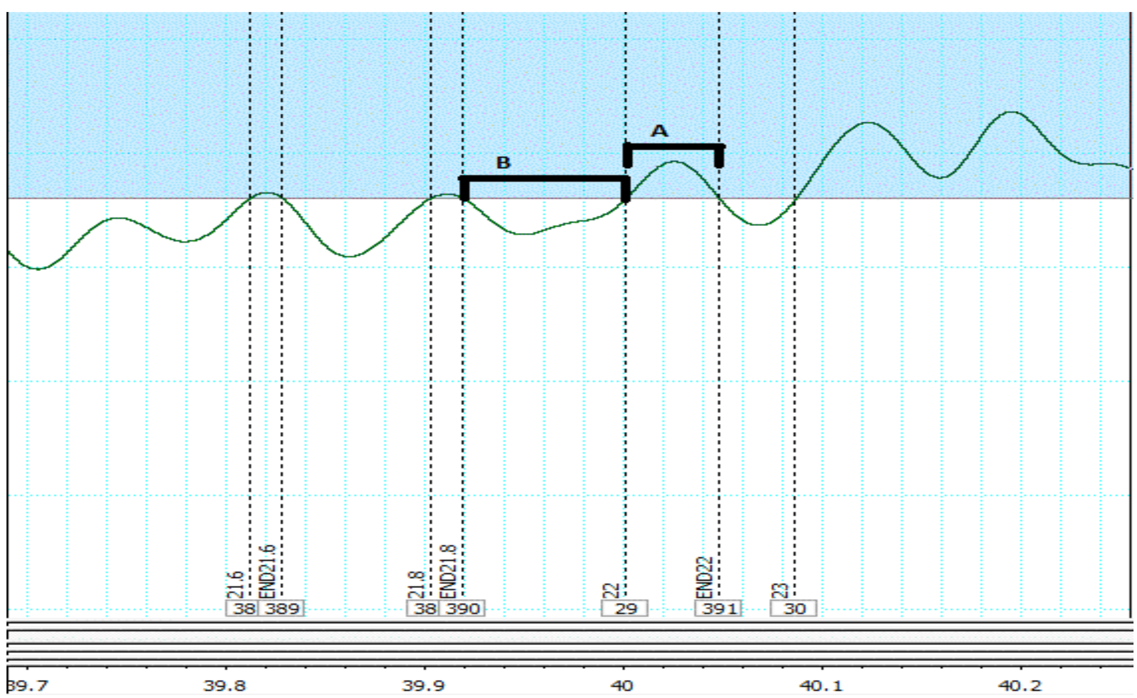

Figure 2. EMG time parameters measured for statistical analysis (horizontal line= threshold; y-axis= muscle electrical activity, measured in millivolts, x-axis= time measured in seconds; A= threshold period, B= length of time between each threshold period).

Results

Participants

Originally five participants were recruited for the study, but two participants, one violinist and one cellist, were unable to complete the trial due to experiment time constraints. The three participants who completed the study included one violinist and two cellists. The first subject, Cellist 1, was able to complete eight biofeedback sessions. The other subjects, the Violinist 1 and Cellist 2, completed three biofeedback sessions each.

Statistical Analyses

There was decrease in the number of threshold periods between the base-test and the post-test of all three subjects (Fig. 3), but no significant difference was found between the post-test and base-tests (paired t-test, $p=0.2568$) or between subjects (ANOVA, $p=0.3142$). Both cellist subjects experienced over a 50% decrease in the number of threshold periods between the base-test and the post-test. The violinist experienced just under a 50% decrease in the number of threshold periods.

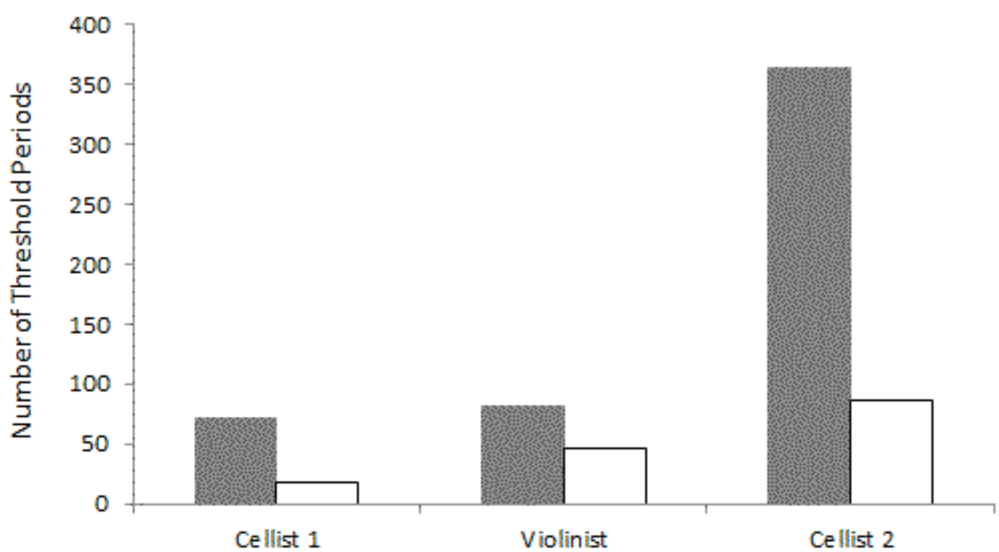

Figure 3. Number of threshold periods shown in base-tests (gray) and post-tests (white).

No clear pattern was observed for changes in the average length of time each threshold period lasted (Fig. 4). No significant difference was found between average length of time of the threshold periods for the base-test and post-test of each subject (paired t-test, p = 0.846). The only subject to experience a decrease in the average length of time of threshold periods between the base-test and the post-test was Violinist 1.

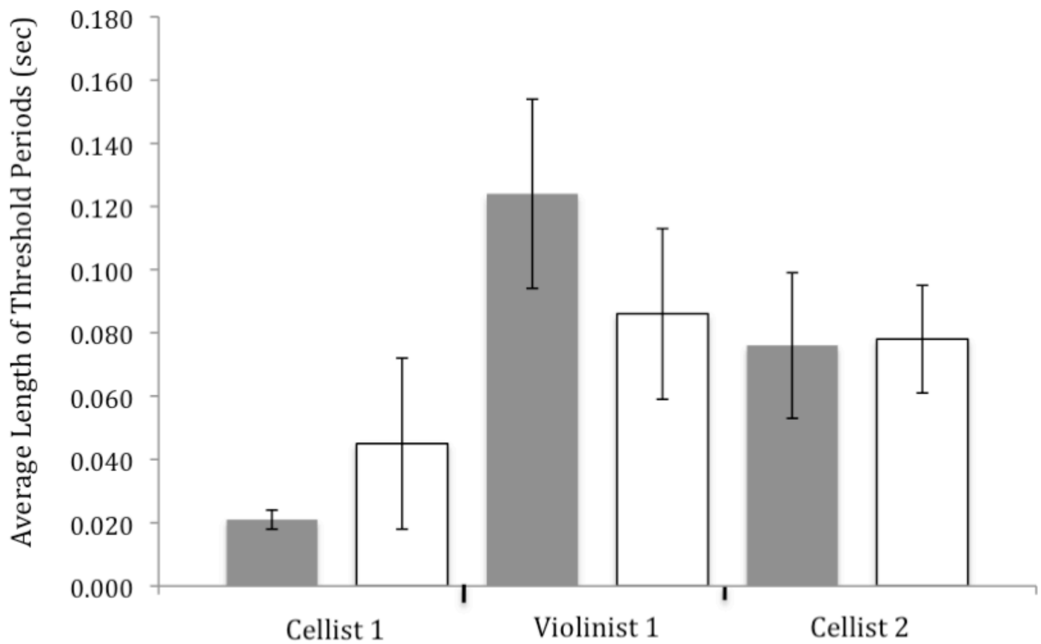

Figure 4. Average length of time of threshold periods (mean±SE; gray=base-test, white=post-test).

All three subjects experienced an increase in the average length of time between each threshold period (Fig. 5), but no significant difference was found between the average lengths of time between threshold periods of the base and post-tests (paired t-test, p=0.3033). There was no significant difference between average lengths of time between threshold periods of subjects (ANOVA, p=0.3153). Similar to the results in the number of threshold periods, both Cellist 1 and Cellist 2 experienced a greater change in average length of time between threshold periods between the base-test and the post-test than did Violinist 1.

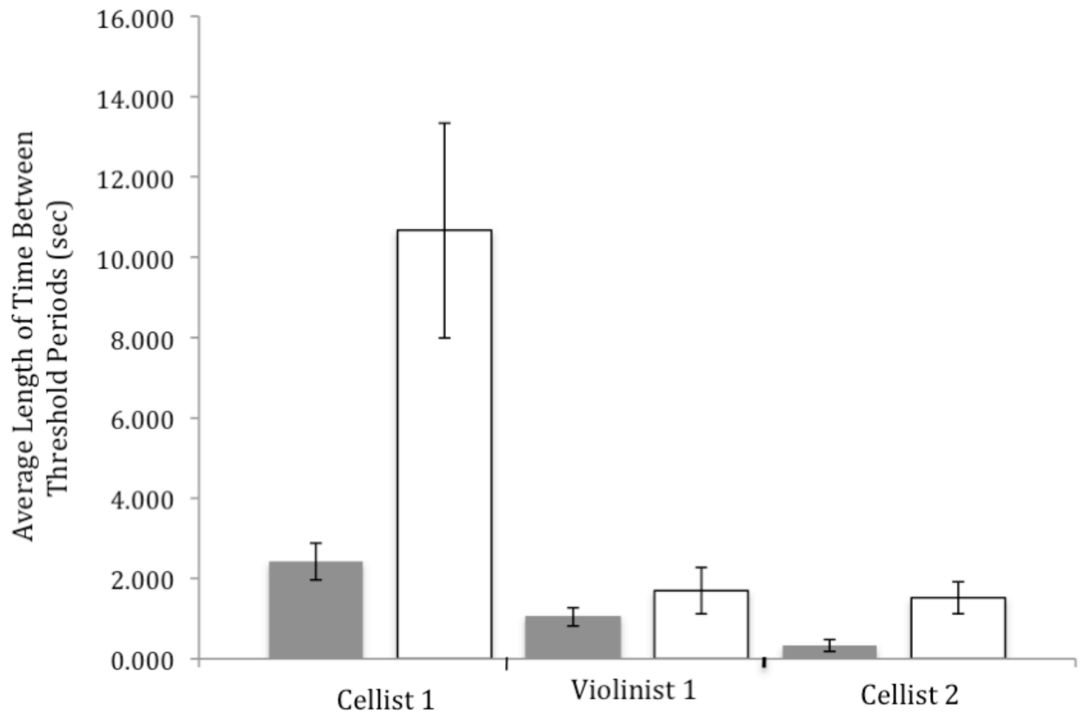

Figure 5. Average length of time between threshold periods (mean±SE; gray=base-test, white=post-test).

Samples of Subject Data

Overall data trends are demonstrated in Figs. 6, 7 and 8. Cellist 1 completed the most biofeedback sessions and had the same threshold throughout all 8 sessions. There was a general increase in the length of time that the subject could play without eliciting the warning tone (Figure 6). Despite having had fewer biofeedback sessions, both Cellist 2 and Violinist 1 showed similar trends.

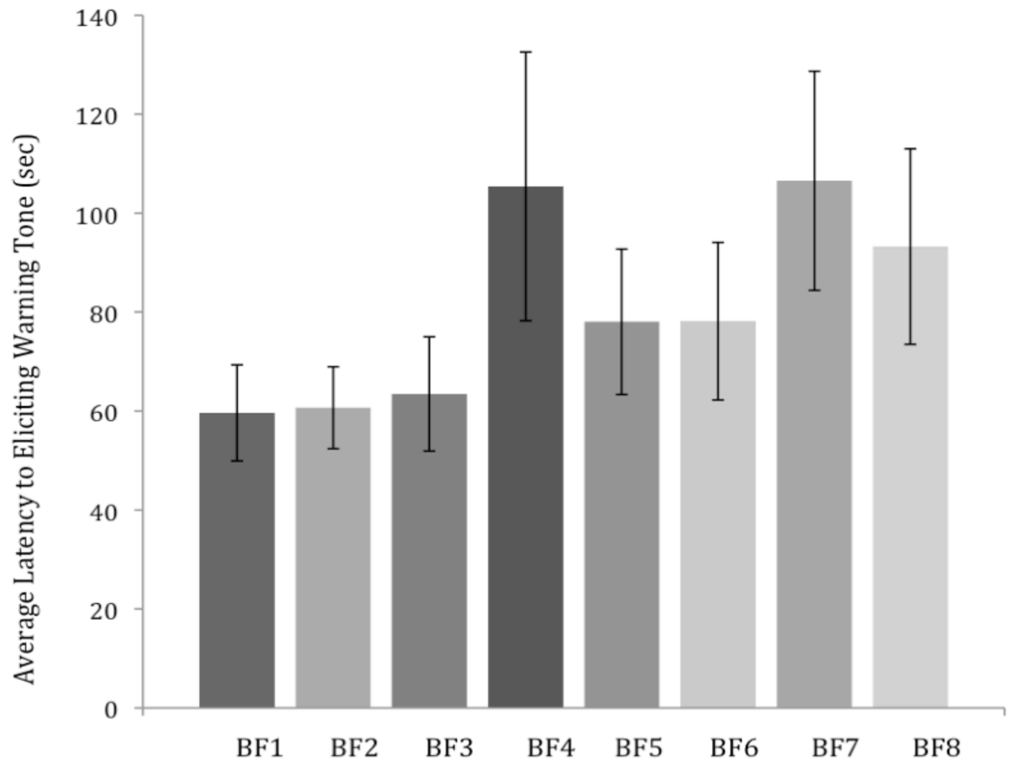

Figure 6. Average latency to eliciting warning tone of Cellist 1 biofeedback sessions (BF=30 minute biofeedback session).

In addition to patterns of fewer threshold patterns and longer latency periods, there were visual patterns of less muscle activity oscillation between the base-tests and post-tests of each subject (Figs. 7, 8). Figures 7 and 8 are screen shots of the EMG data of the base-test and post-test of Cellist 2 at approximately the same part of the piece.

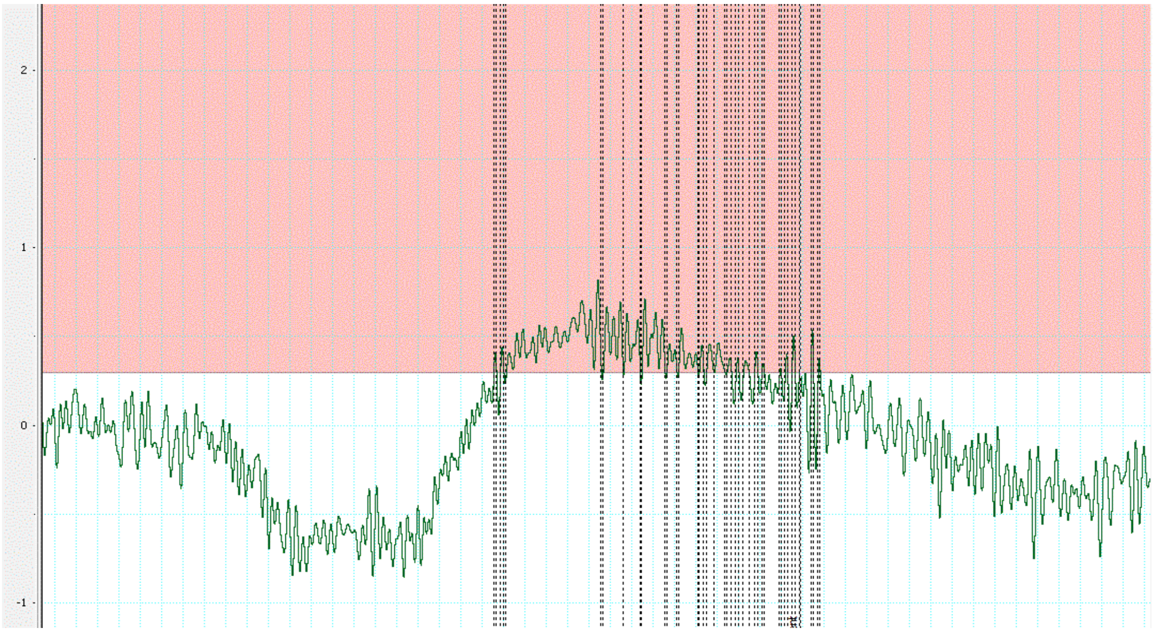

Figure 7. Cellist 2 Base-test at time 2:33 (min), at the end of the piece, Elgar Cello Concerto in E minor, Op. 85. (y-axis= muscle electrical activity, measured in millivolts, x-axis= time measured in seconds)

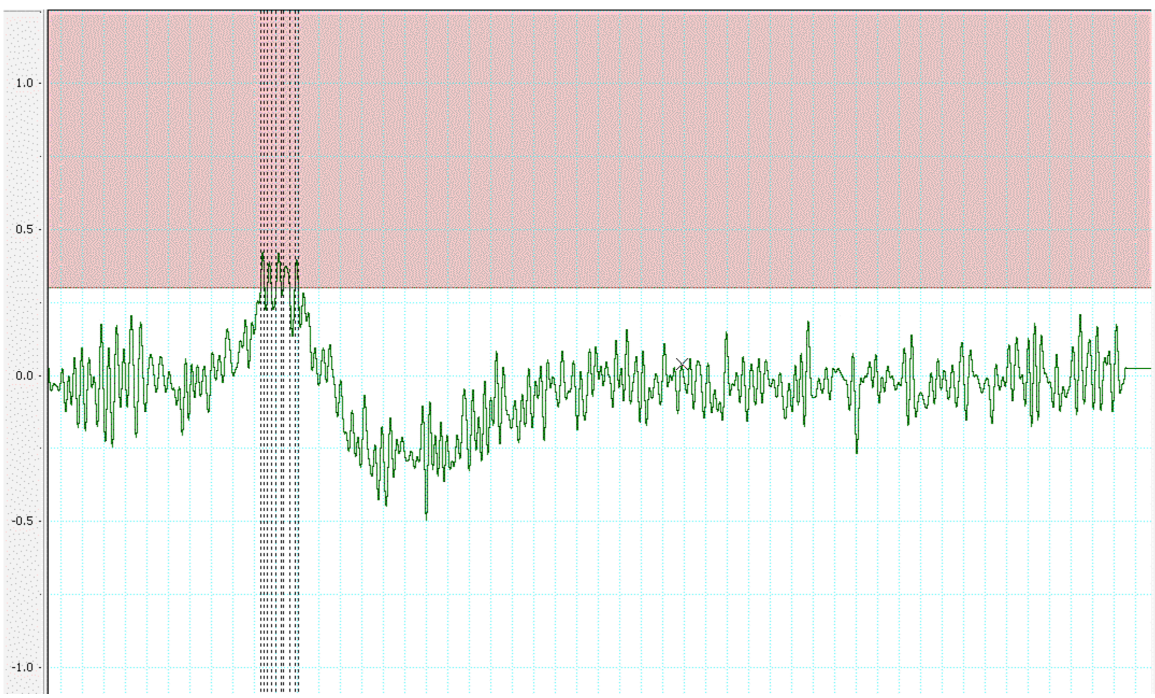

Figure 7. Cellist 2 Post-test at time 2:27 (min), at the end of the piece, Elgar Cello Concerto in E minor, Op. 85. (y-axis= muscle electrical activity, measured in millivolts, x-axis= time measured in seconds)

Participant Surveys

Each subject took a survey at the beginning and end of the experiment in which he or she was asked to evaluate their symptoms on a scale of 1 to 5, with 1 designating nonexistent and 5 designating severe (Table 1). There was an overall trend in decreasing severity of symptoms from the beginning of the study to the end of the study. Only Cellist 1 reported that one symptom, back tension, worsened, but made the note in the survey that the symptom felt more like fatigue from muscles being used more in adjusting posture.

Table 1. Beginning and End of Study Survey Responses (Symptoms rated on a scale of 1-5, 1=nonexistent and 5=severe)

Subject	Before/After	Shoulder Tension	Neck Tension	Forearm Tension	Hand Tension	Digit Numbness	Back Tension
Cellist1	Before	3	1	4	4	2	1
	After	2	1	2	2	2	1.5
Violinist1	Before	3.5	2	1	2	1	5
	After	3	1	1	1	1	3.5
Cellist2	Before	3	1	2.5	2.5	2	3
	After	2	1	1	1	1	1

Discussion

The purpose of this study was to test the hypothesis that the use of EMG biofeedback training in music performance can reduce upper trapezius muscle tension and would be effective in reducing musculoskeletal symptoms characteristic of WRMSDs. Previous EMG biofeedback studies involving string musicians focused on forearm muscle groups and had the musicians play through short, difficult passages (LeVine, Irvine, 1984; Cutietta, 1986). This study was designed based on the trapezius muscle activity patterns demonstrated in string musicians in Fjellman-Wiklund et al. (2004) as well as the idea that muscle tension builds up gradually without the musician being aware of its appearance. Despite lacking significant results, the overall trends in threshold periods and symptom severity indicate that the EMG biofeedback sessions aided in reducing trapezius muscle tension and improving performance comfort.

Study Design

The experiment was designed based on the hypothesis that in music performance, tension builds up gradually without the musician being aware of its appearance. So two of the parameters tested were time based – how long a subject remained above a threshold and how long a subject remained outside a threshold. However, because of the nature of EMG readings and how much they oscillate within a time-span of seconds, this choice of data collection may not have allowed for the most accurate results analysis – for example, in the analysis of Cellist 1 post-test threshold period data, an outlier data point of 0.496 sec skewed the average length of the threshold period. Had this data point been excluded, the resultant average would have been 0.018 sec, demonstrating a decrease in the length of the threshold period from base-test to post-test.

The time-parameter design of this study was beneficial in that it allowed the researcher to compare multiple runs, listen to the subject and observe patterns in tension level and musical technique. For instance, one subject consistently set off the alarm whenever she needed to make an upward, accented motion with her bow arm, while another consistently had higher tension level when the piece transitioned to higher octave passages. Subjects of this study made similar post-study comments to those subjects in previous EMG biofeedback musician studies (LeVine, Irvine, 1984; Cutietta, 1986), expressing that one of the most helpful aspects of the study was being made aware of the location of muscle tension. Additionally, in this study, subjects made the comment that they also became aware of the patterns of muscle tension in their performance, indicating that this is a useful learning technique as well as a therapy technique.

Biofeedback Outcomes

All subjects who completed the study experienced a decrease in the number of threshold periods as well as an average increase in the length of time between threshold periods from the base-test to the post-test (Figs. 3, 5), but no significant effects were found. Two of the three subjects were able to lower their threshold throughout the study, while the third maintained the same threshold, which was the lowest threshold of the three subjects. These patterns indicate that there was an overall decrease in trapezius muscle tension in all three subjects. Both cellists were experienced over 50% decrease in the number of threshold periods between their base and post-tests. The violinist experienced just under 50% decrease in the number of threshold periods and demonstrated the smallest change in average length of time between threshold period of the three subjects. This may indicate that the study was more effective for cellists in reducing trapezius muscle tension, which may relate to the findings presented in Fjellman-Wiklund et al. (2004), that cellists have less static tension load in the upper trapezius muscle while playing, but have a significantly higher tension load.

This may also explain why the violinist was the only subject to experience a decrease in the average length of time of threshold periods (Fig. 3). Violinists have to prop their instrument on their shoulder thus requiring a static level of tension in the left shoulder while performing (Fjellman-Wiklund et al., 2004). This experiment may have been effective in allowing the violinist to decrease that level of static tension to a level that is necessary to support their instrument but not excessive.

The lack of a definable pattern in changes in average length of threshold period may also be explained by the time-parameter measurement. There was an overall trend in decreasing muscle tension. However, as each subject adjusted and muscle tension levels changed, sometimes the muscle activity transitioned from long threshold periods to a period of a lot of shorter threshold periods or maintained a longer threshold period but at a lesser magnitude. These variations in changes in muscle activity appeared to be individual. Fjellman-Wiklund et al. (2004) found that there was a lot of individual variability in playing technique and EMG trapezius muscle activity patterns and that even when playing the same piece there was variability in playing technique.

It should also be noted that Cellist 1, who experienced the greatest increase in average length of time between threshold periods from the base-test to the post-test, had eight biofeedback sessions whereas the violinist and Cellist 2 were only able to schedule three biofeedback sessions. However given that the latter two subjects were able to lower their thresholds and experienced a similar level of change in the number of threshold periods, this difference is likely not a huge contributing factor.

Survey Outcomes

At the start of the study, all three subjects exhibited at least four symptoms (Table 1). By the end of the study, all three subjects felt that the study helped them to reduce tension in their bodies while performing and rated that at least three of their symptoms had reduced in severity since the beginning of the study. Only one subject, Cellist 1, experienced additional muscle tension in the upper back, but further explained that it was not so much muscle strain and tension, but rather muscles that felt they were being worked. This may indicate that in training her body to keep her shoulders from hunching with tension, other muscles in her upper back were being used to do so. Such findings may indicate that strengthening exercises in combination with biofeedback training would be very beneficial to musicians. Little et al. (2008) found that chronic pain subjects with 24 lessons in the Alexander Technique showed about the same amount of improvement as chronic pain subjects with 6 lessons in the Alexander Technique and exercise, indicating that developing a program with multiple intervention techniques may be just as effective or provide more long-term benefits than one intervention alone.

Other survey findings included responses to questions about their performance mentality and their own biofeedback experience. All subjects at the start of the study felt that the muscle tension interfered with their performance due to a lack of comfort and endurance and two of the subjects had some anxiety surrounding the tension in their bodies when performing. By the end of the study, all three participants felt that they had become more aware of their body posture and movements and that they had a better understanding of when and why they tense up when playing their instrument. Some participants also indicated that it helped to have some understanding of biofeedback and how it works as well as to be working with a researcher who was a musician herself. In her review of musician injuries, Heinan (2008) noted that health care providers often do not have a good understanding of the physical and psychological demands of music performance. These survey responses support the idea that subjects and researchers benefit more when there is shared knowledge and understanding. Additionally, all three participants believed they learned valuable techniques and left the study with the belief that it had provided them with long-term benefits.

Study Limitations

The small sample size, lack of a control group and lack of a follow-up test were obvious shortcomings of this experiment. Of the original five participants, only three subjects were able to complete the study, attending the base and post-tests and 3-8 biofeedback sessions. There was no control in this study: all three subjects received the biofeedback treatment. A control group would have allowed for a comparison of progress between individuals who experienced biofeedback training and individuals who did not. A follow-up test was unable to be performed due to the time constraints of this experiment. In their study examining the effects of EMG biofeedback as an intervention for computer workers, Faucett et al. (2002) found that at a 72-week follow-up, subjects still showed improvement but had diminished since the end of the study. A follow-up in this study would have provided more information on the long-term benefits of biofeedback.

Conclusions and Future Studies

This research shows that EMG biofeedback training can be helpful in reducing trapezius muscle tension in musicians. The trends of reduced number of threshold periods and increased length of time between threshold periods and the corresponding reports of reduced symptom severity lend support to the idea the EMG biofeedback sessions can be used as a therapy as well as a training technique. Possible applications of this study include the incorporation of EMG biofeedback into musical pedagogy and training courses, therapy for musculoskeletal injuries and discomfort and music performance coaching. Further studies should investigate a possible alternative to the time-parameters used for data analysis, different muscle groups for different instrumentalists and incorporating biofeedback sessions as a means for long-term improvement.

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