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Impact of Different Bowing Techniques on Upper Trapezius Muscle Tone and Stiffness in Violinists: A Cohort Study

Keman Sanatçılarında Farklı Yay Tekniklerinin Üst Trapezius Kas Tonusu ve Sertliği Üzerindeki Etkisi: Kohort Çalışması

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ABSTRACT Objective: One of the most important health problems today is musculoskeletal disorders of the neck and upper extremities related to occupational activities. These disorders occur in occupational risk groups that require prolonged static postures or repetitive manual tasks. Therefore, the aim of this study was to investigate the effects of different bowing techniques on the upper trapezius muscle (UTM) tone and stiffness in intermediate-level violinists. **Material and Methods:** The study included 14 violinists with a mean age of 25.28±7.57 years. Participants' neck range of motion, UTM tone, and stiffness were assessed using the MyotonPro device. The bowing techniques evaluated were detached tail, detached tip, and large bowing technique. Repeated measures analysis of variance was used to analyze both muscle tone and stiffness across the bowing techniques. Bonferroni correction was applied as a "post hoc" test. In all statistical analyses, $p<0.05$ was considered the level of significance. **Results:** There was no significant difference in UTM tone and stiffness between bowing techniques on the right side ($p>0.05$). However, while there was no significant difference in UTM stiffness, there was a statistically significant difference in UTM tone on the left side ($p=0.01$). **Conclusion:** The UTM tone is higher in the large bowing technique. There was no significant difference in pain and posture assessments between the bowing techniques.

Keywords: Musculoskeletal disease; muscle tonus; neck muscles; overuse

ÖZET Amaç: Günümüzün en önemli sağlık sorunlarından biri mesleki faaliyetlere bağlı boyun ve üst ekstremite kas-iskelet sistemi rahatsızlıklarıdır. Bu rahatsızlıklar, uzun süreli statik duruşlar veya tekrarlayan manuel görevler gerektiren mesleki risk gruplarında ortaya çıkmaktadır. Bu nedenle çalışmanın amacı, orta düzey kemancılarda farklı yay tekniklerinin üst trapezius kası (ÜTK) tonusu ve sertliği üzerindeki etkilerini araştırmaktır. **Gereç ve Yöntemler:** Çalışmaya yaş ortalaması 25,28±7,57 yıl olan 14 kemancı dâhil edildi. Katılımcıların boyun hareket açıklığı, ÜTK tonusu ve sertliği MyotonPro cihazı kullanılarak değerlendirildi. Değerlendirilen yay teknikleri ayrık kuyruk, ayrık uç ve büyük yay tekniğidir. Yay teknikleri arasında hem kas tonusunu hem de sertliği analiz etmek için tekrarlanan ölçümler varyans analizi kullanılmıştır. Bonferroni düzeltmesi "post hoc" testi olarak uygulanmıştır. Tüm istatistiksel analizlerde $p<0,05$ anlamlılık düzeyi olarak kabul edilmiştir. **Bulgular:** Sağ taraftaki yay teknikleri arasında ÜTK tonusu ve sertliği açısından anlamlı bir fark yoktu ($p>0,05$). Bununla birlikte, ÜTK sertliğinde anlamlı bir fark bulunmazken, sol tarafta ÜTK tonusunda istatistiksel olarak anlamlı bir fark vardı ($p=0,01$). **Sonuç:** Geniş yay tekniği ÜTK tonusunda anlamlı bir artışa neden olmuştur. Ağrı ve postür değerlendirmelerinde yay teknikleri arasında anlamlı bir fark yoktu.

Anahtar Kelimeler: Kas iskelet sistemi hastalıkları; kas tonusu; boyun kasları; aşırı kullanım

One of the most important health problems today is musculoskeletal disorders of the neck and upper extremities related to occupational activities.[1] These disorders occur in occupational risk groups that require prolonged static postures or repetitive manual tasks. Musicians are one such occupational group where overuse syndromes and neck pain are common.[2] Musicians often perform in static positions

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with repetitive muscle activities that require high fine motor skills under the precise control of the musculoskeletal system. This can lead to repetitive strain injuries and performance-related musculoskeletal disorders (PRMDs). Moreover, PRMDs are not only seen in musicians but also in music students. Repetitive movements and static postures can increase the load on joints and muscles, causing pain.[3] This can also lead to increased muscle tone as well as increased muscle activation.[4] Epidemiologic studies have shown an increasing prevalence of PRMDs among musicians.[5] Among musicians, those who play stringed instruments, such as violinists, are at the highest risk. The neck, jaw, shoulders, hands, and back of violinists are the most affected body parts.[6]

Playing the violin involves asymmetrical use of the upper extremities.[6,7] The left forearm muscles show more activity than the right forearm muscles, while both upper trapezius muscles (UTM) exhibit constant static muscle activity.[6] It has been reported that violin techniques are not limited to bowing techniques but also include the way the violin is held, the frequency of maintaining abnormal postures, and the force applied by the violinist, especially during fast pieces.[3] The right arm, responsible for bowing techniques, encounters highly constrained movements when players perform while seated, leading to increased loads on the muscles and joints, particularly in the arm and neck.[3]

The term "muscle tone" is defined as the stiffness of skeletal muscles at rest, indicating a steady state without voluntary contraction. It can also be characterized by other mechanical properties of the muscle, such as elasticity or stiffness. Violinists often use different bowing techniques that can lead to overactivation of the shoulder and forearm muscles, especially in the right arm holding the bow. Additionally, different bending movements can alter the activity of muscles, particularly the trapezius, in challenging directions.[5] When playing the violin, the instrument is stabilized with the upper arm, shoulder, and chin; the left hand and forearm move on the keyboard, and the right arm performs bow strokes with dynamic movement. The movement analysis and muscle activation involved in violin playing are very complex. Therefore, to understand the muscle activation that occurs while playing the violin, it would be appropriate to investigate it by focusing on specific body parts and playing techniques. This approach aligns with the direction of current literature.

Violinists require different bending techniques in the right arm, and the activation of neck-shoulder muscles, particularly the trapezius, varies with each technique. Since trapezius muscle activity is affected, biomechanical properties of the tissue such as muscle tone and stiffness may also be impacted.[8,9] Electromyography (EMG) studies have demonstrated that violinists exhibit increased trapezius muscle activation while practicing bowing techniques with the right hand. Although there are studies in the literature showing that bowing techniques increase activation in the trapezius muscle, we did not find a study comparing the tone and stiffness of the trapezius muscle across three different techniques.

This study aims to identify which bowing technique may lead to an increase or decrease in muscle tone and stiffness. This knowledge can help violinists, especially professionals, to be mindful of techniques that may put them at risk of injury or pain in the long term. In light of this information, we examined 3 different techniques, considering that the techniques used by musicians affect the tone of the UTM. The aim of the study was to evaluate how the tone and stiffness of the UTM change with three bowing techniques (the large bowing, detached tip, and detached tail).

MATERIAL AND METHODS

PARTICIPANTS

Power analysis was performed to determine and the sample size was found to be 14, (with an effect size (f) of 0.3, $\alpha=0.2$, and $(1-\beta)=0.80$). The study included 14 violinists (5 male, 9 female) with a mean age of 25.28±7.57 years. All participants were intermediate performers and had been playing the violin for at least 3 years. A signed consent form was obtained from participants who agreed to take part in the study. The study was approved by the ethics committee of Çankırı Karatekin University Health Sciences (date: November 10, 2023, no: 10). Intermediate players between the ages of 20 and 40, who had been playing the violin for at least 3 years and did not have any pain or limitation of neck movement, were included in the study. Individuals who had pain in the neck and shoulder area, who had been diagnosed with cervical disc herniation, who used painkillers or regular medication, and who had not played the violin in the past year were excluded.

EVALUATION PROCEDURE

Neck range of motion was evaluated in participants who agreed to be included in the study. Those without limitations were accepted into the experiment. The cervical range of motion of all participants was measured using a tape measure for neck flexion/extension, right/left lateral flexion, and rotation as described in the reference article.[10,11] Participants were asked to fill out the participant evaluation form. To determine the norm values for each participant in the resting position, UTM tone (right/left) was measured at the widest point of the muscle using the MyotonPro (Myoton AS, Estonia) device on both sides. Their posture was assessed using the Reedco Posture Scale (RPS) before they started playing the notes. The assessments were performed in the resting position before and immediately after the application of the techniques.

OUTCOME ASSESSMENTS

Playback evaluation procedure: The piece to be played was chosen as a beginner-level violin note and was sent to the practitioners for practice approximately one month before the evaluation.

The piece: The placement of the left hand on the notes A, F#, D, and B (A: la note, F#: fa sharp note, D: re note, and B: si note) was determined to be arranged medially lateral to the body. In the arrangement of these notes, the left hand presses all the strings, and the fingers are placed neither too much laterally nor too much medially (Figure 1). Thus, right trapezius activation is not affected by the left hand.

FIGURE 1: Position of the left hand on the strings while playing the note scale

- They sat in a chair without back support as well as without any violin heavy jewelry on neck and arm. Both playing and measurements (resting and after each technique) were obtained in the sitting position.
- Important anatomical parts of the body, such as the acromion, were marked, and photographs of the participants were taken from the lateral and posterior directions to determine the correct posture.
- The neck or chin rest of the violin was not removed.
- For the UTM, the probe of the device was positioned 2 cm lateral to the centre between the lateral edge of the spinous process of C7 and the acromion.
- In resting position both sides of UTM tone and stiffness were measured with the MyotonPro device (Figure 2).

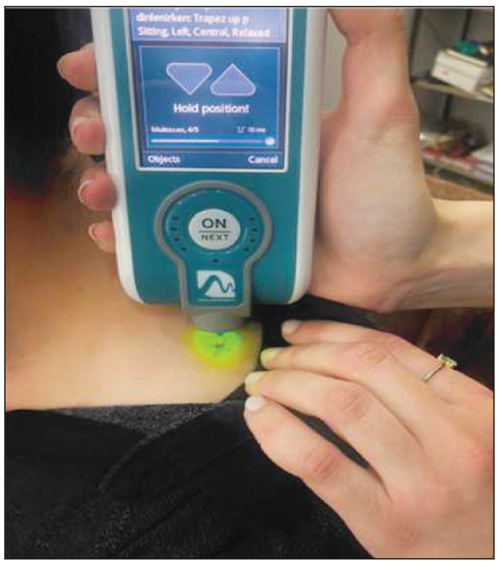

FIGURE 2: MyotonPro applications on UTM (muscle belly was marked with a pencil)

- Then, they were asked to take a playing position.
- The strings of the left hand were A, F#, D, and B, and the right hand was responsible for three bowing techniques: detached tail, detached tip, and large bowing.
- The 3 beats of 60 bpm metronome sound were listened to by the players so that starting time would be equal for all participants.
- Players were asked to play these notes for 3 minutes for each bowing technique without resting and with listening to the tempo, 60 bpm (not too fast, not too slow) for providing bowing control.
- There was a 3-minute rest between each bowing technique.
- At the end of each bowing technique were immediately measured.
- The musicians practiced the techniques in different orders to avoid sequencing errors.
- After all techniques, participants' neck pain was measured using the Visual Analog Scale (VAS) on a scale of 0 to 10.

MYOTONPRO DEVICE

The MyotonPro device (Myoton AS, Tallinn, Estonia) was used to evaluate the tone and stiffness of the UTM. This tool helps to determine even minor changes in muscle stiffness. Additionally, the MyotonPro shows good to very good inter-rater and intra-rater reliability for measuring muscle stiffness, making it an objective reference for measurement. It provides the muscle oscillation frequency in hertz to measure muscle tone. The frequency of muscle tone during rest and isometric contraction varies between 16-40 Hz. The measurement of UTM stiffness is defined as the resistance of the muscle tissue to the applied force, expressed in force units (N/m). It varies between 150-300 N/m and 1000 N/m in resting and isometric contraction (https://myoton.com/quick-instructions-for-use).

REEDCO POSTURE SCALE

Posture is defined as the alignment and orientation of body parts relative to each other. In this study, the postures of the participants were determined using the RPS. Developed in 1974, this scale is a standardized method for evaluating the entire body using sagittal and coronal planes. The RPS is easy to apply and widely used for assessing posture. With this scale, the body is evaluated observationally from both lateral and posterior aspects in terms of 10 postural characteristics. Lateral evaluation includes the neck, upper back, trunk, abdominal, and lumbar region using the sagittal plane, while posterior evaluation includes the head, vertebrae, shoulders, hips, and feet using the coronal plane.[11]

STATISTICAL ANALYSIS

SPPS 29 (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.) statistical package program was used to evaluate the data obtained from the study. Repeated measures analysis of variance was used to analyze both muscle tone and stiffness across the bowing techniques. Bonferroni correction was applied as a "post hoc" test. In all statistical analyses, $p<0.05$ was considered the level of significance.

RESULTS

This study was conducted with healthy violin players (n=14, age: 25.28±7.57 years). The demographic characteristics of participants, including mean age, height, weight, body mass index, gender, and hand dominance, are presented in Table 1.

TABLE 1: Demographic characteristics of participants

	$\bar{X}$ (n=14)	SD
Age (years)	25.28	7.57
Weight (kg)	63.50	9.60
Height (cm)	167.92	8.22
BMI (kg/m^2)	22.45	2.53
	n	
Gender (male/female)	5/9	
Hand dominance (right/left)	14/0	
Profession		
Mainly performing	2	
Academic student	2	
Other	10	

SD: Standard deviation; BMI: Body mass index

TABLE 2: Neck pain score and stiffness and tone values of the UTM (L/R)

		Resting Position X̄±SD	Detache Tip technique X̄±SD	Detache Tail Technique X̄±SD	Large Bowing X̄±SD	F	p value
UTM (R)	Tone (Hertz)	16.88±1.17	17.10±0.88	17.49±1.04	17.58±1.26	3.059	0.39
	Stiffness (N/m)	319.64±44.86	312.28±43.28	328.50±42.05	330.28± 63.31	1.147	0.34
UTM (L)	Tone (Hertz)	18.94±1.59	18.19±2.31*	19.17±1.83	19.73±2.52*	4.175	**0.01**
	Stiffness (N/m)	361.00±60.57	355.42±74.96	368.21±64.11	385.64±85.42	2.620	0.06
VAS			4.00±1.69	3.00±0.00	2.25±2.06	1.42	0.28
RPS Total			93.33±7.63	86.66±11.54	93.75±7.90	0.77	0.48

*Indicates significant difference between Detache Tip Technique and Large Bowing Technique p<0.05. SD: Standard deviation; UTM: Upper trapezius muscle; R: Right; L: Left; VAS: Visual analog scale; RPS: Reedco Posture Scale

UTM STIFFNESS AND TONE VALUES BETWEEN DIFFERENT BOWING TECHNIQUES

There was no significant difference in UTM tone and stiffness between bowing techniques on the right side (p>0.05). However, while there was no significant difference in UTM stiffness, there was a statistically significant difference in UTM tone on the left side (p=0.01). The statistically significant difference within groups was between the detached tip and large bowing techniques (Table 2). There was no significant difference in the VAS values between bowing techniques (Table 2).

DISCUSSION

The main findings of the present study were that there was only a significant difference in left UTM tone values between the detached tip bowing and large bowing techniques. The large bowing technique caused a significantly different tonus increase in the UTM. However, it was found that although UTM stiffness increased between techniques, it did not differ significantly. There were no differences among techniques in the context of pain and postural conditions. When muscle tone and stiffness of the UTM were analyzed as left and right, it was seen that the left side had higher values. It is also noteworthy that both muscle tone and stiffness values of the left UTM were at the upper limit of the reference values of the Myoton device (for muscle tone: 12-18 Hz; for muscle stiffness: 220-380 N/m). Additionally, it should be noted that the measurement method is relatively new.

Unlike our findings, studies in the literature comparing different techniques have shown that right UTM activity was higher, although the percentage varied. Superficial EMG (sEMG) was used in all these studies. Additionally, in some studies, the participants consisted of a population with mixed instrument use.[7] A study conducted by S. Duprey in 2007 observed that muscular activity is affected by tempo; a tempo of 120 bpm, which is fast for musicians, causes 18% higher muscular activations.[12] In our study, we asked our participants to play at a tempo of 60 bpm, which is slow. According to the literature, in difficult pieces on the violin, higher UTM activity is needed. In our study, we asked them to play an intermediate note scale to eliminate other factors as much as possible.

Researchers have shown that there is no difference between left-hand static grip techniques.[13-15] Differences in experimental designs and measurements of the studies have led to varying results in the literature. Studies have mostly focused on right forearm activity. One study focused on playing speed and examined changes on right forearm muscles activity with acceleration and deceleration in some notes of a scale.[13] There are also studies on constant elevation of the arms All these studies focused on muscle activities with EMG.[7,13-15] We did not find any studies that measured muscle tone as in our study.

In contrast to other studies, muscle tone was measured in the current study. Muscle tone differs from muscle activity measured by sEMG. Muscle tone usually refers to the baseline sEMG level in a relaxed state.[16] Unlike EMG, muscle tone also includes the effects of passive and viscoelastic components necessary for muscle activity.[17] Bernstein suggested that muscle tone might reflect a state of readiness for movement.[18] That is, muscle tone is an active contributor to the creation of movement. Similarly, Carpenter et al. defined tonus as "the sustained muscle activity necessary as a background to actual movement, especially to maintain the body's basic posture against the force of gravity".[19] Additionally, researchers have stated that muscle tone is necessary for motor control of both static and dynamic tasks in the most thermodynamically efficient and safe way.[16] Based on this information, we can conclude that an increase in muscle tone after playing may limit preparation for and performance of subsequent movement.

The strengths of the study include its good experimental design, the use of a standard music piece, and its distinction from other studies in terms of assessing muscle tone and stiffness. However, this study has some limitations. Evaluating the violin playing technique on the tonus of other muscles, especially the forearm muscles, could have enabled us to determine the effect of the techniques on both static or dynamic contraction of extremity muscles.

The increase in the left UTM tonus value suggests that it may cause neck pain in the long term due to prolonged working time and repetitive use. Among the bow techniques, the detached tip technique can be recommended to reduce neck problems. While the current study provides a perspective to reduce the risk of injury, it also indicates the need for future studies to form a clear opinion. Long-term studies or comparisons with individuals experiencing neck pain can reveal this situation in the future.

CONCLUSION

- This study is the first to show that muscle tone in the left UTM was at resting level when the detached tip bowing technique was applied.
- The large bowing technique resulted in a significantly higher left UTM tone than the resting and detached tip bowing techniques.
- There was no difference in stiffness or tone in the right UTM.
- We suggest that the detached tip technique is the safest among the three techniques.
- Violinists should prefer the detached tip technique more to reduce long-term pain or PRMD.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: *Defne Sönmezışık;* ***Design:*** *Çiğdem Yazıcı-Mutlu;* ***Control/Supervision:*** *Çiğdem Yazıcı-Mutlu;* ***Data Collection and/or Processing:*** *Defne Sönmezışık;* ***Analysis and/or Interpretation:*** *Defne Sönmezışık, Çiğdem Yazıcı-Mutlu;* ***Literature Review:*** *Defne Sönmezışık, Çiğdem Yazıcı-Mutlu;* ***Writing the Article:*** *Çiğdem Yazıcı-Mutlu;* ***Critical Review:*** *Çiğdem Yazıcı-Mutlu;* ***References and Fundings:*** *Defne Sönmezışık, Çiğdem Yazıcı-Mutlu;* ***Materials:*** *Defne Sönmezışık.*

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