The Influence of Neck–Shoulder Pain on Trapezius Muscle Activity among Professional Violin and Viola Players:

An Electromyographic Study

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Abstract—Work-related musculoskeletal disorders in the neck–shoulder area are common among violin and viola players. The aim of this study was to investigate the influence of playing-related musculoskeletal disorders (PRMDs) on muscle activity, by measuring electromyographic activity in the upper trapezius (UT) muscles of violin and viola players under three experimental conditions: rest, performance of an easy piece, and performance of a difficult piece. Ten professional violin and viola players from a Scottish orchestra volunteered to take part in the study. Five subjects complained of pain in the neck–shoulder region; five were pain-free. Bilateral surface electromyography (EMG) was used, following submaximal reference voluntary contractions, to record the muscle activity of the UT muscles during the three experimental conditions. Subjects were randomly allocated to the conditions. A four-factor balanced analysis of variance (ANOVA) was performed. The results revealed that the pain-free subjects developed more UT muscle activity than subjects experiencing neck–shoulder pain ($F = 4.07$, $df = 1$, $p = 0.05$). Furthermore, the subjects developed significantly more UT activity when progressing from the rest condition to performance of the difficult piece ($F = 36.64$, $df = 2$, $p < 0.001$). The PRMD subjects developed more UT activity than the pain-free subjects at rest. The opposite tendency was observed for the playing conditions. However, the results were not statistically significant for this interaction ($F = 1.85$, $df = 2$, $p = 0.169$). The results suggest that redistribution of the load to other synergistic muscles may be a strategy used by PRMD subjects to alleviate pain or discomfort at the neck–shoulder area. The voluntary monitoring of shoulder muscle activity may be of great importance in the prevention of PRMDs in viola and violin players. *Med Probl Perform Art* 17:68–75, 2002.

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INTRODUCTION AND LITERATURE REVIEW

Prevalence of Playing-related Musculoskeletal Disorders

Musculoskeletal problems among professional musicians are in most ways no different from musculoskeletal problems associated with any other occupation; most types of work require that certain bodily movements and positions be used in a repetitive manner.[1,2] Throughout the 1980s and 1990s, numerous epidemiological studies were undertaken in an attempt to identify the incidence, prevalence, nature and severity of playing-related musculoskeletal disorders (PRMDs) experienced by musicians.[3-8] Following her systematic review, which highlighted the heterogeneity of these studies, Zaza[2] found that the prevalence of PRMDs in musicians ranged from 39% to 47%, when mild and transient complaints were excluded, with PRMDs defined as "pain, weakness, numbness, tingling, or other symptoms that interfere with (their) ability to play (their) instrument at the level (they) are accustomed to."[9]

The largest published study ever undertaken involving professional orchestra musicians surveyed a population of 4,025 musicians from 48 orchestras (the International Conference of Symphony and Opera Musicians: ICSOM) in the United States in 1986.[5] With a response rate of 55%,[2] this study reported that 76% of musicians had at least one medical problem severe enough to affect their performance. String players, whose playing requires both repetitive actions[10] and static loading,[11] had the highest risk of PRMDs (66% prevalence), with the neck and shoulder being the prime sites affected.[5,6] By combining location of PRMD, instrument, and gender, the researchers found that female violin players had a significantly higher percentage ($p < 0.05$) of severe problems in both shoulders and both sides of the neck. The prevalence was also higher among female viola players.[6]

Playing-related Musculoskeletal Disorders and the Violin/Viola Player

Caldron et al.[3] attempted to explore the nature of these complaints, and concluded that the vast majority of PRMDs fell into four categories: overuse tendinitis; muscle cramps and occupational palsies; nerve entrapment syndromes; and bone, joint, and bursal injuries. Nevertheless, even in the absence of detectable physical pathology,[12,13] there is some evidence to suggest that complex repetitive movements, involving prolonged static and dynamic loading of muscles, are contributory factors in producing PRMDs.[10] This is particularly appropriate when the violinist's or violist's posture is considered: a raised left shoulder, the instrument supported on the left supraclavicular fossa, left rotation and side-flexion of the head, abduction and full external rotation of the left arm, left forearm supination, a dropped right shoulder, and internal rotation and abduction of the bowing arm with forearm pronation.[10,14-18]

Electromyographic Investigations on Violin Players

Although many electromyographic (EMG) studies have used the upper trapezius muscle to gain information on muscle work during occupational work,[19,20] few have focused on the effects of PRMDs and stressful conditions on the activity of this muscle in violin and viola players.

Levy et al.[21] used EMG analysis to compare muscle activities in the upper arm muscles of violin players ($n = 15$) with and without a shoulder rest under three conditions. The results revealed a significant reduction of the rectified EMG signals in the left trapezius ($p < 0.03$) and right sternocleidomastoid ($p < 0.01$) muscles when the shoulder rest was used. Nevertheless, the EMG data were not normalized, and did not therefore allow comparisons between subjects.

Philipson et al.,[22] more specifically, compared normalised, averaged, and rectified EMG results bilaterally on deltoid, upper trapezius (UT), biceps, and triceps muscles in nine professional violin players. Despite a small, unbalanced sample size between the PRMD and pain-free groups, and less-than-optimal electrode placement (electrodes centered over the middle part of the muscle),[19] they found that subjects affected by PRMDs produced significantly more muscle force than their unaffected counterparts for the right deltoid, the right biceps, and both left and right upper trapezius ($p < 0.05$).

Psychological Stress and Muscle Hyperreactivity

Performance-related anxiety, a playing-related health problem evidenced in the ICSOM survey by 16% of respondents as being a severe problem, cannot be ignored as another possible component that may affect the severity of existing PRMDs.[5] Indeed, Flor et al.[23] hypothesized that the development and maintenance of chronic musculoskeletal pain may be the result not only of physical causes but also of other psychological variables, suggesting that some individuals may be predisposed to respond to stress with a hyperreactivity of certain muscles.

In addition, Moulton and Spence[12] proposed that muscular hypertension may eventually lead to ischemia of the affected muscles, generating a pain–tension–pain cycle. Larsson et al.[24] studied 76 workers (with long-standing unilateral neck pain and diagnosed chronic trapezius myalgia) using laser Doppler flowmetry to measure muscle blood flow, and surface EMG of both UT muscles during a fatiguing series of stepwise increased static loads. They concluded that the increased muscle tension on the painful side ($p < 0.05$) may be secondary to impaired microcirculation of the muscle ($p < 0.05$), and the consequent release of nociceptive substances, thereby maintaining the pain–tension–pain cycle.[12,24]

Study Aim

The aim of the present study was to investigate, by means of surface EMG analysis, muscle activity in the UT muscles in two groups of violin and viola players: one group of players with pain in the neck–shoulder area; the other were pain-free. Players performed under three experimental conditions: a rest condition, performance of an easy piece, and performance of a difficult piece. It was hypothesised that:

1. Professional violin and viola players experiencing neck–shoulder pain would experience more UT muscle activity than players with no pain.
2. Professional violin and viola players would have different levels of UT muscle activity when performing the rest condition, easy piece, or difficult piece.

METHODS

Ethics

The study was approved by the Research Ethics Committee at Glasgow Caledonian University. All participants provided written informed consent.

Subjects

Ten professional violin and viola players from a professional Scottish orchestra volunteered to participate in the study, following a meeting with the violin and viola sections of the orchestra.

Professional musicians were defined as "musicians who play in occupational orchestras and attend practice sessions scheduled by the orchestra."[25] Two groups of five players were formed, a PRMD group and a pain-free group, and matched as closely as possible according to gender and instrument played (Table 1).

Group Assignment

In order to determine the two groups, a brief questionnaire, piloted with three musicians, was used to obtain information about the musicians (Table 1), including the presence or absence of PRMDs in the neck–shoulder area. For those

TABLE 1. Sample Characteristics

	PRMD Group (n = 5)		Pain-free Group (n = 5)	
Characteristic	*Mean*	*SD*	*Mean*	*SD*
Age (in years)	34.00	4.47	36.17	5.81
Number of years of professional playing	13.92	4.08	11.83	6.55
Number of hours of weekly practice	26.50	3.21	27.50	2.81
Allocation of subjects according to instrument and gender	*Violin*	*Viola*	*Violin*	*Viola*
Male	1	1	1	1
Female	1	2	2	1

complaining of PRMDs, more information was gathered regarding site and severity of pain using body charts and a 10-cm horizontal visual analog scale. Pain descriptors adapted from the McGill-Melzack Pain Questionnaire were used to complement information on pain intensity.[26]

Skin Preparation and Electrode Placement

Skin preparation, to reduce skin impedance, involved: shaving the shoulder area, where necessary; abrasion with an eraser; use of alcohol wipes; and drying of the area with paper towels.[25,27]

Bilateral bipolar recordings were made using self-adhesive electrodes (blue sensor disposable electrodes, type M-00-S, 4mm diameter, Medicotest UK Ltd., St. Ives, England) placed on the descending fibers of the UT, with an interelectrode distance of 45 mm center to center. The electrodes were oriented parallel to the muscle fibers, and placed on either side of a point 2 cm lateral to the midpoint of the line between the seventh cervical spinous process (C7) and the lateral edge of the acromion process.[19,20,28,29] The two ground electrodes were placed on the spinous processes of C7 and T2[25,28] (Fig. 1).

Normalization Procedure

Subjects were seated in a standard chair (height: 47 cm, depth: 42 cm, width: 47 cm, no armrest), as used during rehearsals and performances, and were then asked to hold both arms straight and horizontal in 90° abduction, in the frontal plane, hands relaxed and palms pointing downwards,[20,29-31] while holding a 1-kg weight in each hand.[20,28,30,32] The head and trunk were maintained in an upright position, with no lateral flexion or rotation,[19,30] while a 15-second EMG recording was taken.[19] This procedure was repeated four times, with a 1-minute rest pause between EMG recordings,[19] while the subject's arms rested on his or her lap.

This reference voluntary electrical activation (RVE) procedure, obtained during the isometric submaximal reference voluntary contraction (RVC), was used on the grounds that: it is more appropriate to violin playing, which involves low force requirements of the upper trapezius; it is presumably less sensitive to fatigue than a maximum voluntary electrical activation (MVE);[28] problems of validity are associated with an MVE; and current research has questioned the translation of the EMG amplitude from the UT ($EMGamp_{UT}$) into bio-

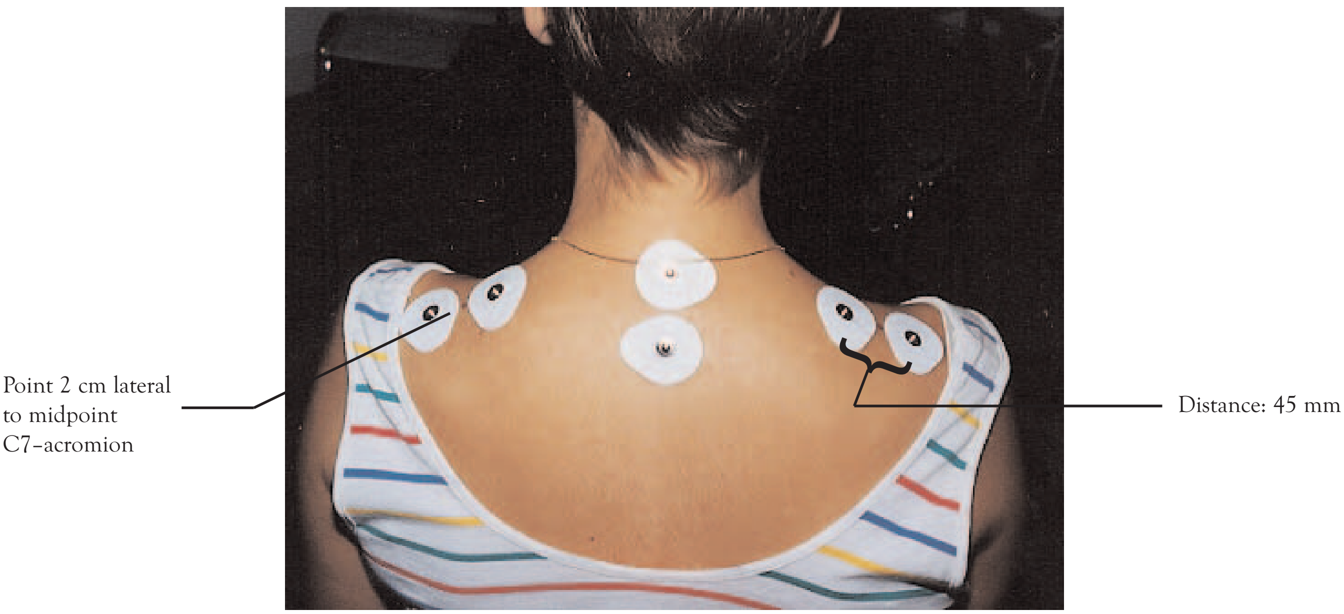

FIGURE 1. Electrode placement.

FIGURE 2. Easy piece for violin: Vivaldi—*Four Seasons*.

mechanical variables (%MVC or %RVC).[19,20,28,30] The RVE corresponded to the mean of the four rectified and averaged EMGs calculated over a 10-second window during the normalization procedure. The RVE was expressed in microvolt-seconds (μVs).

EMG Data Collection

Subjects were seated as indicated previously, and all players used their own shoulder rest while playing, since a significant reduction in EMG activity of the left UT was demonstrated when a shoulder rest was used.[21] The three experimental tasks were randomized and balanced in both groups between subjects.[33] Each condition was repeated three times. In the rest condition, the subjects were asked to remain relaxed with head and trunk upright for 30 seconds with both arms alongside the body. A 12-second EMG recording was then taken in this position, timed using a stopwatch. Since investigation of fatigue was not the aim of the present study, a lengthy playing session was therefore not appropriate. Furthermore, Philipson et al. demonstrated that a 6-second session was adequate to yield statistically significant results,[22] and several studies have failed to detect fatigue during long periods of occupational work at low load levels.[19]

Following a 1-minute rest, the players were asked to take up their playing position. Once ready, they were given four metronome beats before playing either the easy or the difficult piece. For the easy piece (Fig. 2), the subjects were required to play only in the first position of their instrument (position of the hand at the scroll end of the finger board), thereby limiting fingering changes and leaps across the finger board of the violin/viola. The difficult piece (Fig. 3) involved frequent changes in positions and fingering. The 12-second EMG recording session corresponded to 16 beats being played at 80 beats per minute for both pieces. The metronome, previously tested for accuracy and precision, was kept running during performance to ensure that all subjects played for exactly the same length of time. Precise measure-

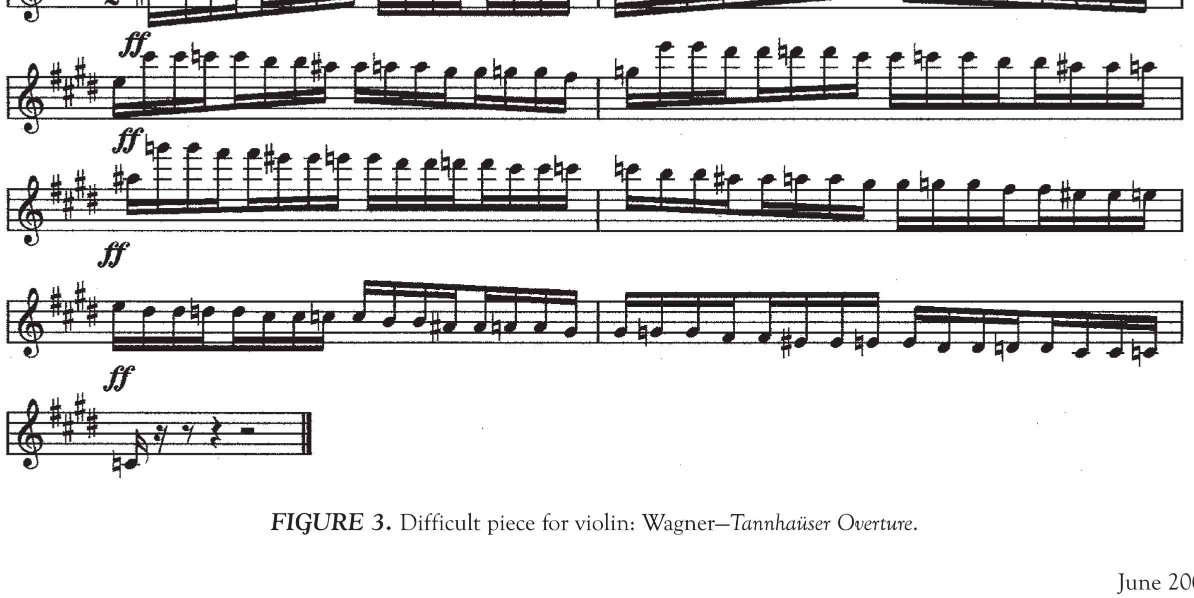

FIGURE 3. Difficult piece for violin: Wagner—*Tannhaüser Overture*.

TABLE 2. Four-factor Analysis of Variance (Balanced Designs) for the Means of Averaged and Rectified Electromyographic Values, Expressed in %RVE

Source	DF	SS	MS	F	p-value
Subjects	4	8,230.4	2,057.6	8.04	0.000
Limb	1	280.4	280.4	1.10	0.301
Group	1	1,040.6	1,040.6	4.07	0.050
Task	2	18,756.6	9,378.3	36.64	0.000
Limb * group	1	201.9	201.9	0.79	0.379
Limb * task	2	700.4	350.2	1.37	0.265
Group * task	2	945.6	472.8	1.85	0.169
Error	46	11,772.6	255.9		
TOTAL	59	41,928.5			

ment of the beginning and end of each EMG recording was ensured by using a switch-marker, operated by the researcher. All rest pauses were timed using the stopwatch. The researcher was the only person giving instructions and operating all equipment. Standardized instructions were used throughout all testing sessions. The coefficients of variation, which were calculated in order to ascertain test–retest repeatability of the normalization procedure and the experimental tasks, ranked between 4.64% and 13.90%, in line with recent research.[19,30]

EMG Data Reduction and Analysis

The surface EMG signal was picked up at the electrodes and amplified by the EMG apparatus (Multi Signal System ME3000P8, Mega Electronics Ltd., Kuopio, Finland). The electrodes were connected to a pre-amplifier with a gain of 375; in turn this was connected to the ME3000P8 portable EMG sampling unit resulting in a total gain of 412, a high-pass filter set at 8 Hz, and a low-pass filter set at 500 Hz. The amplifiers had a common mode rejection ratio of 110 dB. The signal was then sampled at 1,000 Hz, as recommended in the manufacturer's instructions, by a 12-bit analog-to-digital converter. The raw EMG data for each recording were rectified; the average EMG activity for a 10-second window[19,28,30] were calculated using specific software (Multi signal ME3000P version 3.0). The mean of the three averaged EMGs for each task was expressed as a percentage of the RVE (%RVE).

TABLE 3. Electromyographic Values (in %RVE) Described According to the Factor "Group"

Group	Mean	SD	F	p-value
PRMD* group	26.250	23.683	4.07	0.05
Pain-free group	34.579	29.138		

*PRMD = playing-related musculoskeletal disorder.

TABLE 4. Electromyographic Values (in %RVE) Described According to the Factor "Experimental Task"

Experimental Task	Mean	SD	F	p-value
Rest condition	6.578	8.962		
Easy piece	35.792	21.091	36.64	0.001
Difficult piece	48.874	26.352		

Statistical Analysis

Minitab version 12.0 (Minitab Inc., State College, PA) was used for descriptive and inferential statistics. A four-factor balanced analysis of variance (ANOVA) was performed, with $EMGamp_{UT}$ as the dependent variable (Table 2). Diagnostics were performed, after the model was fitted, to ascertain normality and homoscedasticity.[33] All tests were performed using a 5% level of significance ($\alpha = 0.05$).

RESULTS

Comparison of PRMD and Pain-free Groups

The results revealed a significant trend : pain-free subjects developed more upper trapezius (UT) muscle activity (approximately 9 %RVE) than subjects experiencing neck-shoulder pain ($F=4.07$, $df=1$, $p=0.05$). There was a considerable degree of inter-subject variability, as indicated by the large standard deviations (Table 3).

Comparison of Experimental Tasks with Respect to UT Muscle Activity

The results showed that professional violin and viola players developed more UT activity during both playing conditions than during the rest condition. Additionally, the subjects showed an increased UT activity with increased difficulty of the piece to be performed (Table 4). The results considered both limbs together and were significant ($F = 36.64$, $df = 2$, $p < 0.001$). However, the ANOVA model does not differentiate which variances are statistically significant (Table 4).

Comparison of the PRMD and Pain-free Groups According to Experimental Conditions

The results in Table 5 show a trend similar to the one observed in Table 4 with regard to the factor "experimental task": in both groups, professional violin and viola players

TABLE 5. **EMG Values (in %RVE) Described According to the Factors "Group" and "Experimental Task"**

Group	Rest Condition	Easy Piece	Difficult Piece	F	*p*-value
PRMD group					
Mean	7.933	29.758	41.059		
SD	10.314	20.323	25.647		
				1.85	0.169
Pain-free group					
Mean	5.223	41.826	56.688		
SD	7.686	21.099	25.933		

TABLE 6. **EMG Values (in %RVE) Described According to the Factors "Limb" and "Experimental Task"**

Limb	Rest Condition	Easy Piece	Difficult Piece	F	*p*-value
Left UT*					
Mean	7.440	35.382	41.936		
SD	8.669	25.070	29.259		
				1.37	0.265
Right UT					
Mean	5.716	36.202	55.811		
SD	9.630	17.613	22.427		

*UT = upper trapezius.

developed more UT activity during both playing conditions than during the rest condition. Moreover, the subjects showed an increased UT activity with an increased difficulty of the piece to be performed. When considering the two groups, the results revealed the trend already identified earlier, but only for the playing conditions. On the contrary, for the rest condition, the PRMD subjects showed higher UT activity than the pain-free subjects (Table 5). However, the ANOVA revealed that the results were not significant with regard to the interaction between the factors "group" and "experimental task" (F = 1.85, df = 2, $p = 0.169$) (Table 2).

Comparison of Experimental Conditions According to Left and Right UT

Interestingly, although this was not one of the aims of the present study, the comparison between experimental conditions according to left and right limbs indicated a difference between left UT activity and right UT activity during performance of the difficult piece compared with the other two conditions: players developed more UT activity for the right limb (Table 6). However, the ANOVA revealed that the results were not statistically significant (F = 1.37, df = 2, $p = 0.265$) (Table 2).

DISCUSSION

Comparison of the PRMD and Pain-free Groups

The present study did not demonstrate that professional violin and viola players experiencing neck–shoulder pain show more UT muscle activity than pain-free subjects. This is contrary to the findings of Philipson et al.,[22] which showed significantly higher EMG levels in both trapezius muscles of PRMD violin players compared with pain-free players. However, in their study, Philipson et al.[22] described their subjects as being unable, at the time of investigation, to perform professionally due to their PRMDs, suggesting a very high severity and/or irritability of painful episodes. In the present study, the majority of PRMD players described a moderate level of pain intensity when using the visual analog scale (0 to 10): from 3.28 ± 2.23 to 5.62 ± 3.35 with regard to the different sites of pain in the neck–shoulder area. This difference in pain levels suggests that it may be possible that players suffering from severe pain in the neck–shoulder area are more prone to develop an increased UT muscle activity as a result of the pain–tension–pain cycle previously described. On the contrary, when the pain level is lower, the discomfort at the cervical and shoulder region may trigger the players to compensate by redistributing the load to other synergistic muscles. Indeed, Palmerud et al.[34] showed that healthy subjects could, by means of visual feedback, voluntarily reduce the EMG activity of the trapezius muscle by 33% during an arm elevation task, and distribute the load to other muscles, particularly rhomboid major, rhomboid minor, the transverse fibers of trapezius, and serratus anterior. An ability to alternate between different strategies of shoulder muscle engagement could therefore be useful, in working situations where the trapezius muscle suffers from overuse, to unload exposed muscles.[34] This may be worth investigating in a future study dealing with violin and viola players.

These considerations may also explain why the conclusions drawn by Larsson et al.,[24] indicating an increased UT activity on the painful side secondary to impaired microcirculation during muscle contractions, were not observed in the present study. However, muscle blood flow, using laser Doppler flowmetry, was not measured in the present study, a variable that may be worth exploring in a future study.

However, the causes of discomfort at the neck–shoulder region may not be entirely attributed to the UT muscle: high intramuscular pressures, impeding muscle blood flow, have been found in the supraspinatus and infraspinatus muscles during prolonged static work with elevated arms,[35] and could explain the physiological stress on the rotator cuff muscles, possibly resulting in chronic disorders around the shoulder joint. Furthermore, other structures such as tendons, nerves, bones, joints, and bursae may be sources of complaints.[3,15] Finally, the objective measures obtained from the EMG signal may not be sensitive enough to explore sources of pain arising from other areas.[25]

Comparison of Experimental Conditions

Influence of Physical Load

With regard to the experimental conditions, the results indicated that professional violin and viola players experienced more UT activity when progressing from the rest condition to the difficult piece. In the study by Levy et al.,[21] which constrasts with the present study, statistical significance was not obtained when considering conditions only: static (subjects supported their violin with bow arm at rest); first (subjects played a piece in first position); and shift (subjects played a piece involving frequent shifts in third, second, and fourth positions). However, the "static" condition in the study by Levy et al.[21] involved holding the violin in the playing position, and this would yield more left UT activity than merely keeping the arms at rest alongside the body. When both playing conditions of the present study were considered, the tendency, for all subjects, was toward an increase in UT activity when performing the difficult piece. When the playing conditions were differentiated according to left and right limb, the tendency was similar, but a difference occurred between amounts of left and right UT activity during performance of the difficult piece: players developed more UT activity on the right side, although this was not statistically significant.

Several explanations are possible: the difficult piece was physically more demanding than the easy piece, and required frequent shifts of the left hand on the fingerboard, possibly leading to overstabilization of the shoulder joint and therefore more left UT activity.[36] With regard to the bowing arm, the difficult piece would require an increased speed of the arm to respect the dynamics, and an increased frequency of leaps between the four strings of the instrument in order to play bigger intervals. These factors would lead to greater acromion and lateral epicondyle vertical displacements,[18] possibly causing an increased right UT activity.

Consequently, during violin/viola playing, the right and left shoulders have very different functions: the right shoulder experiences both static and dynamic loading, whereas the left shoulder has a more static role to play. This could explain the difference in EMG activity between left and right UT muscles during performance of the difficult piece. Furthermore, it may be possible that the muscle loading experienced by the left and right UT muscles contributes to the development or maintenance of PRMDs.[10]

Possible Influence of Psychological Stress

Although the present study did not evaluate mental stress separately from physical load, both factors were possibly combined in the performance of the difficult piece, and since the left UT has a more static and less task-dependent role than the right UT, the effects of stress would be more likely to be noticeable on the left side. Since some studies have shown that induced psychological stress led to an increase in $EMGamp_{UT}$, both during standardized static contractions and in the absence of physical load,[37,38] and suggested that psychological stress may play a role in the development of musculoskeletal disorders, the influence of psychological factors in violin and viola players may be worth investigating in a future study.

CONCLUSION

Contrary to what was hypothesized, PRMD subjects developed less UT activity than pain-free subjects. This could be due to redistribution of the load to other synergistic muscles, although this requires further investigation. However, subjects showed more UT activity when progressing from the rest condition to the difficult piece, possibly owing to overstabilization of the left shoulder joint, and greater acromion and lateral epicondyle vertical displacements of the bowing arm during performance of the difficult piece.

Future studies could endeavor to ascertain whether the observed tendencies are reproducible, using a larger group of female subjects only, age-matched, randomly selected from all the professional orchestras in Scotland, and playing the same instrument (either violin or viola). Subjects with mild and transient complaints should be excluded from the PRMD group.

Using needle EMG, rather than surface EMG, on all major neck and shoulder muscles would enable a more specific measurement of muscle activity.

Moreover, the possibility of controlling shoulder muscles voluntarily, and the trapezius muscle in particular, may be of great importance, and provide scope for the development of EMG biofeedback as one of the prophylactic measures to consider in order to alleviate chronic neck–shoulder muscle pain among violin and viola players.

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