The effect of scapula taping on electromyographic activity and musical performance in professional violinists

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Taping the scapula has been suggested as a method of improving both scapula position and muscular efficiency of the shoulder girdle. These factors have been linked to neck and arm problems in violinists. The purpose of this study was to evaluate the effects of taping the scapulae of violinists into a position that prevented excessive elevation and protraction whilst playing. Eight professional violinists played three different musical excerpts with and without scapula taping applied in random order. Electromyographic activity was recorded from the upper trapezii, the scapula retractors and the right sternocleidomastoid muscles. Performances were recorded onto videotape and audiocassette, and self-report data collected for later analysis. Compared with the control condition, scapula taping increased electromyographic activity in the left upper trapezius muscle during playing by 49% as an overall effect, with a 60% increase in the most physically demanding piece played. Lower music quality was detected in the same piece by raters blinded to performance conditions. Taping also had significant negative effects on subjects' reports of concentration and comfort. Short-term application of scapula taping did not enhance selected scapula stabilising muscles during playing and was not well tolerated by professional violinists. **[Ackermann B, Adams R and Marshall E (2002): The effect of scapula taping on electromyographic activity and musical performance in professional violinists. *Australian Journal of Physiotherapy* 48: 197-204]**

Key words: Electromyography; Music; Scapula

Introduction

Upper limb performance-related injuries or pain affect from 50% to 88% of professional violinists (Fry 1986, Hiner et al 1987, Zaza et al 1998). In some of these performers, the necessary static loading in the left shoulder and the repetitive loading of the left hand and right upper limb can cause pain to occur bilaterally in the upper limbs, and the prolonged uneven loading of the cervical spine (in a left laterally rotated and flexed position) may cause premature spinal degenerative changes and neck pain (Fry 1986). Predisposing factors suggested to cause these injuries in violinists include poor proximal shoulder girdle and scapulothoracic joint stability, inefficient muscle use, poor posture, and poor technique (Dawson et al 1998, Meinke 1998, Nagai and Eng 1992).

Scapulothoracic joint stability is thought to be an essential component of dynamic control of the shoulder complex (Hess 2000). One of the main functions of the scapula is to provide stability for the upper extremity during functional activities of the hand, as well as allowing more versatility of the hand by controlling mobility of the proximal humerus (Voight and Thompson 2000). Scapulothoracic positioning is considered to be extremely important for violinists, being the major muscular support for both the weight of the arm and the instrument (Tubiana et al 1989) in their playing position. Violin teachers have been reported to spend almost a quarter of their working day with their arms between 30 and 60 degrees of elevation (Fjellman-Wiklund et al 1998). Another study of violinists and violists found an average of 25 degrees of shoulder flexion whilst playing their instruments (Ross 1999). In this range, most of the movement occurs at the glenohumeral joint, with the scapula playing a stabilising role (Mottram 1997). The static loading required by long hours of violin playing has been reported to cause muscular imbalances around the scapulae and shoulders (Fry 1986) where the scapulae and shoulders may become repositioned to be excessively protracted and elevated, especially on the left side (Paull and Harrison 1997). This forward and raised posture has been suggested to contribute to neck and upper limb injuries in these musicians (Paull and Harrison 1997). The resulting muscle imbalance of this scapula position is associated with comparatively increased activity levels in the upper trapezius in relation to its middle and lower portions (Morin et al 1997).

In terms of the muscles involved in violin playing, the left upper trapezius (shoulder elevation) and right sternocleidomastoid (SCM) muscle (left cervical rotation and chin depression) together have a major role in holding the violin between the left shoulder and the chin (Levy et al 1992). The scapula retractors, particularly the rhomboids and middle trapezius muscles, have an important role in providing scapula stability (Voight and Thomson 2000) and thus in supporting the arm holding the instrument. The left rhomboid major muscle seems to be particularly prone to stresses of static loading in violinists, and has been cited as commonly lengthened and a frequent source of pain (Nagai and Eng 1992), even being referred to as "the violinist's Achilles spot" (Owen 1985).

Table 1. Characteristics of the eight professional violinist participants.

AGE	SEX	PAIN	SITE OF PAIN	IS PAIN RELATED TO PLAYING THE VIOLIN?
44	Female	Yes	Right cervical spine and right arm, left elbow	Yes, many years history of mild intermittent problems
38	Male	No		
31	Female	Yes	Lower back, central distribution	Yes, pain present for several months
40	Male	Yes	Pain bilaterally in cervical spine and shoulders, L > R	Yes, pain present intermittently for 2 years
35	Female	No		
45	Female	No		
28	Female	Yes	Central lower back pain	No (result of childbirth)
47	Male	No		

Taping the scapula is argued to be an intervention that can assist in restoring a better scapula position (Brukner and Khan 2001, Hall 1999, Morrissey 2000, Mottram 1997). There are different methods of scapula and shoulder taping described in the literature for different purposes (Brukner and Khan 2001, Hall 1999, Host 1995, Morin et al 1997, Morrissey 2000). In one method, the scapula is taped into a more "ideal" anatomical position, usually away from a position of excessive protraction (Mottram 1997, Holly and Nash 1996, Host 1995). This type of taping has been cited in the literature as enhancing force production of the scapula retractors by improving their length-tension relationship (Holly and Nash 1996, Host 1995, Morrissey 2000), as being effective in reducing neck and shoulder pain and improving posture of the neck and shoulders (Bennell et al 2000, Brukner and Khan 2001, Holly and Nash 1996).

With respect to the measurement of relative amounts of muscle activity, comparing surface electromyographic activity levels is a useful method for evaluating effects of a short term intervention where electrode positions remain unchanged (Matthiassen et al 1995). The surface electromyographic activity from the upper trapezius muscle is widely used as a measure of shoulder-neck load, with increased activity levels indicative of greater loads and correlated with higher incidences of neck and shoulder pain (Aaras et al 1998). The application of surface electromyography to compare the effectiveness of different interventions has been used previously in studies with musicians (Kjelland 2000, Levy et al 1992, Philipson et al 1990, Ross 1999). Scapula taping has been previously studied in 14 undergraduate violin and viola players. Ross (1999) used surface electromyography on the left anterior deltoid and infraspinatus during the playing of five notes, and compared a left-sided application of scapula taping with the use of an external floor support. The scapula taping had an effect of increasing the electromyographic activity levels in the left anterior deltoid when one note was played, and decreasing muscle activity in the left infraspinatus in one other note played, while the external floor support reduced activity levels in both muscles in all notes played. However, the effect of bilateral scapula taping during violin playing on scapula support musculature has not yet been clarified.

Figure 1. Seated violinist with taping applied to achieve relative retraction of the scapulae.

If taping can be applied to the scapulae of violinists to enhance proximal scapula stability and muscular efficiency by potentially increasing activity levels of the scapula retractors and decreasing upper trapezius and right sternocleidomastoid muscle activity, it could be an appropriate and inexpensive intervention which could be incorporated into the treatment and prevention of overuse or misuse injuries in this professional group.

The purpose of this study was to assess immediate effects of scapula taping, designed to improve scapula position, on overall surface electromyographic activity levels of selected support muscles (the right SCM muscle, bilateral upper trapezius muscles and bilateral scapula retractors)

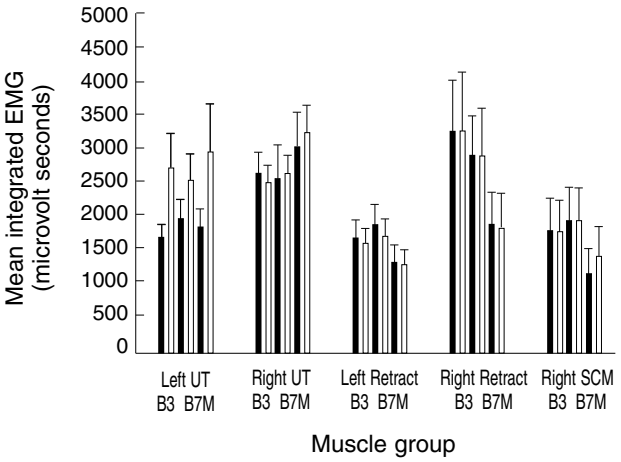

Figure 2. Mean integrated EMG values for the taped and untaped conditions of all muscles and excerpts tested. From left to right, in each muscle, the pairs of bars represent Beethoven 3 (B3), Beethoven 7 (B7) and then Mozart (M). The black bars represent the untaped condition, and the white bars represent the taped condition. The whisker bars represent one standard error.

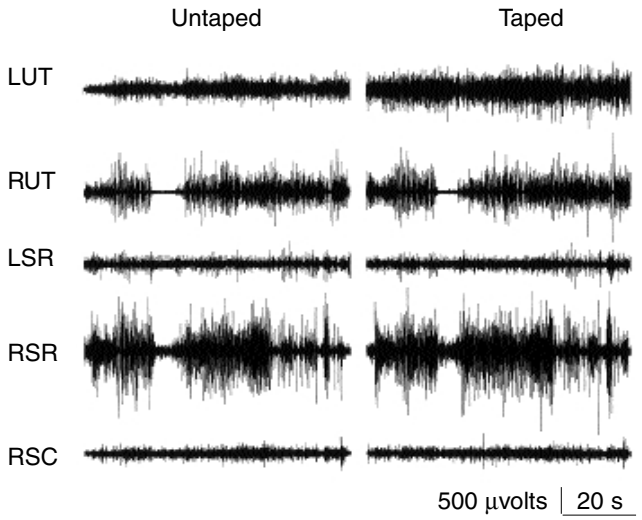

Figure 3. Typical EMG trace of muscle activity levels during the Beethoven 3 excerpt in the untaped and taped conditions. LUT = left upper trapezius, RUT = right upper trapezius, LSR = left scapula retractors, RSR = right scapula retractors, and RSC = right sternocleidomastoid.

while professional violinists were performing short musical excerpts of varying demands. Self-rated and musical performance variables were also analysed to see whether the scapula taping would have concurrent effects in other domains.

Method

Study design The study consisted of a 3 x 2 x 5 factorial design, wherein violinists without previous experience of scapula taping were asked to play three musical excerpts varying in speed and intensity of playing with, and without, scapula taping applied. Recordings were taken from five selected muscles. The order of the taped and untaped conditions was randomly allocated, and then all three excerpts were played in the same order in each condition.

Electromyographic recordings were used to assess the immediate effect of scapula taping on the levels of activity in the muscles involved in instrument support. Subjects were familiar with the musical excerpts used but did not practise them before testing. Two of the excerpts were of one minute duration. One (Beethoven Symphony No 3, 4th movement, violin 1 part) had to be played fast and loud and another (Mozart Symphony in C KV338, 2nd movement, violin 2 part) was slower. A third excerpt (Beethoven Symphony No 7, 1st movement, violin 1 part) was of two-and-a-half minutes duration and had some technically difficult sections. In this last excerpt, an artificial 10 bars rest was inserted midway through the piece (at 80 seconds), to assess the extent to which the muscles would relax during this short pause. A metronome was used for all pieces to standardise the tempo of playing.

Subjects University of Sydney ethics approval for this study was obtained prior to commencement and all volunteers gave informed consent. A sample of convenience comprising eight professional violinists (five females and three males aged 28 to 47 years) working in the same orchestra volunteered to participate. At the time of testing, four of the subjects reported experiencing pain (see Table 1), though at sufficiently low levels that it did not prevent them from playing their normal orchestral repertoires. Each individual 45min testing session was conducted in a private backstage room in breaks during rehearsals. Subjects were asked to dress so that during testing their clothing would not touch the electromyography electrodes.

Taping procedure With both scapulae positioned into slight retraction, violinists were firmly taped with hypoallergenic tape underlay, then rigid sports tape overlying to apply tension (see Figure 1). The pull of the tape into retraction was such that subjects could feel firm support in a neutral position. Morrissey (2000) suggests that if a lengthened underactive muscle is held in a shortened position, then there will be a change in the length-tension relationship of that muscle, with greater force development in the inner range through optimised overlap of actin and myosin during the cross-bridge cycle. Accordingly, taping was based on the Morrissey (2000) diagrams, being used to increase the amount of both scapula retraction and upward rotation of the shoulder, and away from a position of excessive scapula protraction and forward ("downward") rotation. One strip of tape was applied from the acromion to the level of T8, and another from the acromion to the level of T4 (see Figure 1). Taping

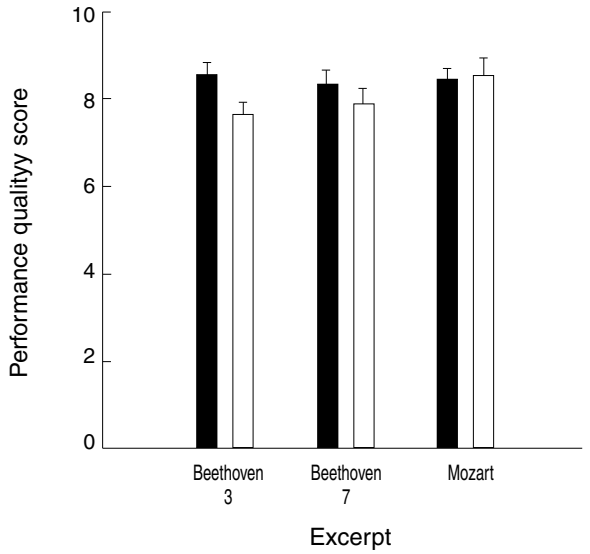

Figure 4. Mean ratings of independent assessors of musical performance quality for the three excerpts in the taped and untaped conditions in the untaped condition (black bars) and taped condition (white bars). The whisker bars represent one standard error.

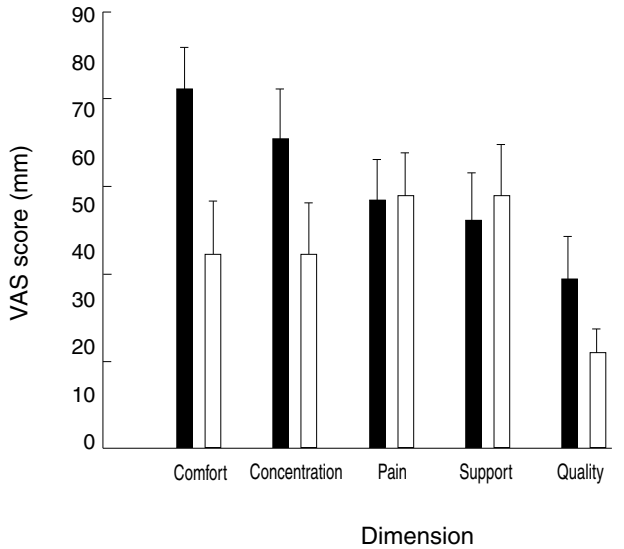

Figure 5. Mean scores of the VAS scales used by the violinists to report on dimensions associated with playing under both conditions with playing in the untaped condition (black bars) and taped condition (white bars). The whisker bars represent one standard error.

therefore shortened the scapula retractors, but still allowed sufficient scapula protraction and elevation to permit the range of flexion, external rotation and adduction of the humerus required for playing the violin. Each performer was tested for adequate functional range following tape application.

Electromyography protocol Muscle activity was recorded using a series of 2cm diameter Ag-AgCl disc surface electrodes, which were placed two centimetres apart over the midline in the centre of the selected muscle belly in the direction of the muscle fibres. Recordings were taken from both upper trapezii muscles, with an electrode on either side of the midpoint between the seventh cervical vertebra and the lateral edge of the acromion (Jensen et al 1996). Scapula retractor activity levels were recorded bilaterally at the level of T5 (midway between T5 and the medial border of the scapula when the arm is adducted), to be close to the central muscle belly of the rhomboid muscles with the middle trapezius muscle overlying. A final set of electrodes was placed over the central belly of the right SCM muscle. Placements were those described by Basmajian and DeLuca (1985). Skin was prepared using sandpaper abrasion and alcohol cleansing. An interruptor signal was used at the beginning of electromyography recordings to accurately indicate the start of playing. Electromyographic data was recorded using a Biopac MP100, 16-channel, 16-bit analog-to-digital convertor and was collected at a sample rate of 2000 Hz, since the suggested sample rate for surface electromyography data is greater than 1000 Hz (Turker 1993). The Biopac MP100 was connected to a notebook computer using the AcqKnowledge software package V3.5.3. Electromyography data was first band-pass filtered at 10-500 Hz then amplified by 2000. The resulting raw data signals were subsequently rectified and smoothed using a one-second (2000 sample points) moving average time window (DeLuca 1997). From these smoothed signals, the 10 minutes of integrated electromyography data (comprising the total area under the graph for the entire time period of each excerpt) was measured, enabling comparison across conditions of the relative amount of muscle activity used.

Musical performance analysis Audio recordings taken of the performances were analysed separately and independently by two examiners who were themselves professional violinists with at least 10 years of experience as violin teachers, and were blinded to both performer identity and condition, taped or untaped. Excerpts were rated on a common grading system where 10 represented the best performance, and the scores given were a composite of the following components: intonation (including mistakes), tone quality, rhythm, shape and ease of melody, and bow control.

Videotape recordings All subjects were recorded on videotape using a single camera placed three metres away. Recording from the left posterolateral viewpoint allowed determination of whether the violin was lowered or head position altered in the artificial break in the Beethoven 7 excerpt.

Subjective data After each of the taped and untaped performances, participants completed a questionnaire, using a visual analogue scale (VAS) format to rate their comfort, pain, feeling of postural support, level of distraction and perceived performance quality.

Statistical analysis A repeated measures analysis of variance with planned contrasts (Winer et al 1991) was carried out on the integrated electromyography data. With the sample of eight, power is greater than 0.8 for within-subjects effect sizes of large magnitude, ie one standard deviation or greater (Cohen 1977). Paired samples *t*-tests were used to compare VAS scores arising from ratings of the taped versus untaped conditions, with SPSS 10 for Windows. All tests were two-tailed with an alpha level set at 0.05 throughout.

Results

Mean integrated electromyography values of all conditions are shown in Figure 2. Analysis of variance on the integrated electromyography data showed no significant overall effect of taping across musical excerpts. There was a significant increase in integrated electromyography with scapula taping in the left upper trapezius muscle, with an overall effect size of 49% (ie 0.83 SD units, $F_{(1,7)} = 7.91$, $p = 0.026$). Analysis of this left upper trapezius effect by musical excerpt showed only a significant effect (60%) during the piece requiring the fastest tempo (speed) and highest volume (intensity) of playing, the Beethoven 3 excerpt, ($F_{(1,7)} = 7.04$, $p = 0.033$). A typical electromyographical trace for the left upper trapezius in this piece in both conditions is shown in Figure 3. For the Beethoven 7 and Mozart pieces, the observed left upper trapezius increases with taping were not statistically significant ($F_{(1,7)} = 4.08$, $p = 0.083$ and $F_{(1,7)} = 3.56$, $p = 0.101$ respectively). Post hoc comparison of maximum muscle activity peaks over the two taping conditions demonstrated no significant differences.

To evaluate the effects of the artificial pause inserted after 80 seconds of playing in the Beethoven 7 excerpt, a mean of the first 70 seconds of playing was chosen to compare with the middle five seconds of the rest period to separate the two conditions. Analysis of the data for all musicians showed a significant reduction in electromyographic activity for left and right scapula retractors, SCM and right upper trapezius, ($F_{(1,7)}$ and *p*-values of 21.9 (0.002), 11.3 (0.01), 10.9 (0.02), and 33.2 (0.001) respectively). Only left upper trapezius activity did not significantly decrease, ($F_{(1,7)} = 1.7$, $p = 0.23$). Noticeably, the one violinist who removed their chin from the instrument and shifted their head and neck posture back to neutral during the break showed reduced left upper trapezius muscle activity levels in both conditions.

Mean results of the audio analysis are presented in Figure 4. Separate ANOVAs showed that both examiners, who were blinded to performer condition and identity, rated playing in the taped Beethoven 3 performance to be of lower quality than playing in the untaped condition (Rater 1 $F_{(1,7)} = 8.29$, $p = 0.02$, and Rater 2 $F_{(1,7)} = 7.25$, $p = 0.03$). No other significant differences were detected.

In VAS ratings made by the players, in relation to the taped and untaped conditions, significant effects were observed during taped performance in terms of greater perceived distraction ($t_7 = -2.95$, $p = 0.022$) and discomfort ($t_7 = -2.96$, $p = 0.021$), but not on other rated dimensions. These results are summarised in Figure 5.

Discussion

During violin playing of varied musical excerpts, scapula taping was associated with increased electromyographic activity levels in the left upper trapezius muscle, with no concurrent reduction in scapula retractor and SCM muscles. The effect was most marked in the excerpt that required most intensity and velocity of playing (Beethoven 3). An explanation of this effect can be made in terms of the biomechanics of violin playing. During vigorous playing, such as required in the Beethoven 3 excerpt, the violin needs to be stabilised more firmly when increased downward force from the bow has to be exerted on the instrument. Thus scapula taping may have acted to restrict forward and upward movement of the shoulder, thereby increasing the amount of isometric tension generated in the left upper trapezius. In this same piece, independent professional analysis of performance quality found a significant audible decrement when it was played in the taped condition compared with the untaped condition. It is likely that the mechanical restriction to movement of the left shoulder arising from scapula taping, and the violinist's straining against this, was the reason for the deterioration in musical performance quality. This tension may also have contributed to the significantly higher levels of discomfort and distraction reported by the violinists when taped. A similar restraining effect may also have occurred with the scapula taping used to prevent anterior impingement of the shoulder in the case study presented by Host (1995).

With dynamic activities such as violin playing, restriction arising from the taping is most likely to be perceived if the musician's posture when taped is very different from normal playing posture. It was noteworthy that one violinist, who the researchers felt showed the most upright posture, was the only subject with no reported differences between playing in the taped condition and playing normally.

The effect in the artificial pause in the Beethoven 7 excerpt, of sustained activity levels of the left upper trapezius, seems explained by the simple fact that most violinists continued to support their instrument with their chins during the pause. Consistent with this, the one observed reduction in electromyographic activity in the left upper trapezius muscle in a violinist in both conditions, was seen to result from taking the chin off the violin and changing neck position back to a neutral posture in this break. Philipson et al (1990) hypothesised that the inability to relax during short pauses may contribute to the development of overuse injuries. The finding here is consistent with the view that relaxation may not occur in short breaks, particularly on the left side which is providing static support. Further investigation could clarify the effects of altering head and neck posture during short pauses on electromyography levels in violinists.

In the current study, there was no immediate increase of the right or left scapula retractor muscle activity as a result of being taped into a relatively shortened position, as had been proposed in the literature (Morrissey 2000). Hall (1999) has suggested that up to two or three weeks of scapula taping may be necessary to improve neuromuscular control and eight to 12 weeks of taping may be necessary to affect muscle length-tension properties. Scapula taping was novel to all the violinists in this study. It is possible, with repeated applications of scapula taping, that habituation to the tape may reduce the negative feedback of participants, or even allow adaptation of neural pathways by consistent correct proprioceptive feedback (Hall 1999, Herrington and Payton 1997). McConnell (1996) likewise suggests that taping of the patellofemoral joint may have an effect over repeated applications in developing new neural pathways for more appropriate levels of muscle activation. However, the repeated application hypothesis cannot be readily evaluated by surface electromyography, due to the poor inter-test reliability of re-applying electrodes identically. Accordingly, this hypothesis of improved taping effects over time has yet to be empirically investigated. Further, increased electromyographic activity levels in the upper trapezius muscle have been previously associated with higher rates of neck pain and sick leave (Aaras et al 1998). The increase in upper trapezius electromyographic activity seen in the current study as a result of scapula taping is a concern in violinists, who already show a high incidence of neck problems. This issue would need to be addressed before longer term trials of scapula taping could be recommended.

The consequences of scapula taping in the current study were not benign, as left upper trapezius activity increases were accompanied by a detectable decrement in performance. This is an important finding in light of the fact that these were highly skilled professional orchestral musicians, trained to adapt to a wide range of environmental conditions (seating, available space, line of sight etc) in order to maintain optimal sound quality.

One implication of the current research is that there may be negative performance consequences of taping in other domains involving elites. Ankle studies have reported tape acting as a strong restraint, and with no proprioceptive effects (Refshauge et al 2000), but sport performance quality has not yet been investigated. Likewise, while some alteration of muscle recruitment patterns and pain and torque improvements have been noted as a result of patellofemoral taping (Gilleard et al 1998) there are no studies investigating these taping effects on elite level performance.

Fatigue effects were not obvious over the 10 minutes (total) of testing, but would not be expected in this group of elite musicians, who normally play for 45 minutes prior to a significant break. Periods of testing over longer periods (two to three hours) have shown no fatigue effects in professional orchestral violinists (Chan et al 2000).

In patellofemoral taping, the patella is taped to obtain a pain-free position (McConnell 1996) whereas the purpose of taping in the current study was to evaluate whether the support provided by taping the scapula had an effect on electromyographic measurements and performance quality. Although numbers were small in this study, there was no effect of the type of scapula taping used on the low levels of pain reported by these violinists. Whether scapula taping can have an impact on high levels of pain in violinists remains to be determined. Due to the impairment of concentration and musical performance levels found in the present study, other benefits would have to be demonstrated before clinicians could recommend the use of scapula taping to elite violinists.

Conclusion

The possibility that scapula taping could have beneficial effects on the pattern of shoulder muscle activity during violin playing was investigated by recording elite musicians playing three short excerpts while taped and not taped. Taping effects only became detectable in the piece requiring more vigorous playing (Beethoven 3 excerpt) where scapula taping was associated with increased left upper trapezius electromyographic activity levels. This was associated with a reduction in musical performance quality detected by blinded independent professional examiners. Subjects reported significant negative effects of taping on their concentration and comfort, but perceived pain and feelings of support were not improved by the taping. Scapula taping therefore requires further research before it could be recommended as an appropriate method of intervention for professional violinists.

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