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***Abstract* –** Musicians often experience overuse injuries due to the repetitive movements they must use to play an instrument, and poor or unbalanced posture can contribute to pain and the likelihood of injury. The purpose of this study is to investigate the effect of the Alexander Technique (AT), a method to improve postural imbalances. Using motion capture technology, violinist and violists were tracked by motion-capture cameras that recorded their movement as they played. The participants played a short etude, watched an instructional video on the AT, and then applied the AT while replaying the same etude. The angular displacements of the head, neck and shoulders, were measured to quantify changes in body posture. There was a statistically significant difference between the pre- and post-AT measurement of the mean distance between the reflective markers placed at the mandibular angle (M = 149.39 SD = 16.74) and acromion process (M = 154.16, SD = 18.88), (t = 4.36, p = .01). There was no statistically significant difference between the pre- and post-AT measurement of the mean distance between the reflective markers placed at the C3 spinous process (M = 117.96, SD = 17.08) and the occipital bone (M = 126.5, SD = 11.36), (t = 2.02, p = .30). However, the mean distance was larger in three of the four participants. The results of this preliminary, pilot study indicated that the AT produced a measurable change in the potential to reduce the amount of tension and influence the unconscious postural habits that violinists and violists experience.

I. Background

Music is a universal language understood by all and it allows those who play instruments to develop and convey a form of self-expression and skill that applies to multiple areas of life. Through developing proficiency of concentration, fine motor skills, and efficient learning techniques within the experience of an art form, those who play instruments gain valuable life skills. However, playing a musical instrument can be a lead cause of injuries among instrumentalists and many of these injuries can go unseen until a physician's expertise is pursued. Musicians often experience overuse injuries due to the repetitive movements they must use to play an instrument, and poor or unbalanced posture can contribute to pain and the likelihood of injury.

While musicians are recognized as artists, they must also be considered athletes with the use of their fine motor skills and long hours of repetitive movement. At some point in an athlete's life, they will experience pain or discomfort due to their sport. Generally, there are measures in place for athletes to verbalize these issues and receive necessary treatments. However, according to a study by Rickert, Barret, and Ackermann (2015), student musicians in particular may be prone to demonstrating poor health awareness and verbalization of pain if it is experienced. Failing to bring up practice-related pain has the potential to lead to overuse injuries that can jeopardize a musician's future ability to play. Such overuse injuries are determined by pain in tendons, joints, ligaments, and muscles. Additionally, tissue damage can also occur from constant use over time due to poor posture, playing style, or lack of professional instruction.

Common Musician Injuries

While it is commonly expected that athletes will likely sustain injuries of some kind during training or games, the same expectation is generally not extended to student musicians. In an article by Ackerman and Chan (2014) on physical therapy for musicians, the authors note that while sports medicine focuses actively on making sure athletes are watched closely for injury and given strong medical support networks, there is little equivalent support for musicians.

Common musician injuries include a variety of muscular and neurogenic components and involve joints, tendons, muscles, and ligaments. Posture, playing style, and biological traits also play a factor in the characteristics that can determine injury susceptibility. From the neurogenic side, tendonitis and nerve compression are two common types of musician injury. Tendonitis occurs when tendons become inflamed due to muscle overuse. The resulting pain can seriously compromise a musician's ability to play and can persist at rest or in motion. Additionally, tendonitis can be experienced at a single site, or spread throughout several physical locations. Trigger finger is a specific form of tendonitis that affects the palm and fingers, while De Quervain's Disease is an inflammation that occurs at the base of the thumb (Lukomski, 2004).

Nerve compression injuries can be caused by body structure and/or incorrect posture and generate weakness around the compression site along with numbness or tingling. Carpal tunnel syndrome, Pronator Teres Syndrome, Wartenburg Syndrome, Bowler’s Thumb, Flexor Tenosynovitis, and Guyon’s Canal Syndrome all fall under nerve compression injuries that musicians can be at risk for (Lukomski, 2004). Carpal tunnel causes a numbness and tingling on or around the thumb, ring finger, middle finger, and index finger, and cubital tunnel syndrome produces tingling pain at the inner elbow, particularly when bent. Thoracic Outlet Syndrome involves hand or arm fatigue, coldness, tingling, pain, and discoloration of the hand. Pronator Teres Syndrome leads to weakness and pain down the wrist and the hand, while Wartenburg Syndrome is indicated by numbness and pain on the outside of the wrist and the side of the thumb (Lukomski, 2004). Flexor Tenosynovitis presents with numbness of the median fingers during and immediately after playing. Bowler’s thumb causes numbness and tingling of the thumb, while Guyon’s Canal Syndrome can lead to weakness and decreased sensation of the pinky and ring finger (Lukomski, 2004).

In addition to the physical complications that may arise from playing a musical instrument, there are psychological complications that may exacerbate the likelihood of a musician developing an injury. In a study conducted by Rickert, Barret, and Ackermann (2015), student cellist majors at a New Zealand college were surveyed to gauge their injury awareness in relation to their instrument. The authors found a strong indication that the student musicians possessed poor health awareness and were unlikely to pay attention to their injuries when contrasted with their professional counterparts (Rickert et al., 2015). Many of the student cellists indicated that pain was something they simply dealt with. One piano/cello student admitted to experiencing pain when playing but then going so far as to say that he was still able to continue with twelve hours of rehearsals per day, demonstrating a troubling indifference to his physical pain signals (Rickert et al., 2015).

Common Violinist Injuries

For violinists and violists, pain signals are important as injury can lurk in both general and specific areas. Playing a violin or viola requires fine motor skills and repetitive movement of specific muscles. In a study by Hagberg, Thiringer, and Brandstrom (2005), neck, shoulder, elbow, and forearm pain was found to be more predominant in violinists and violists than it was in pianists. For violinists and violists, upper extremities including neck, shoulder and joints in the jaw are often affected first because of the head and shoulders being flexed for a prolonged period during playing (Nymann et al., 2007). Beyond general arm and shoulder discomfort, elbows and fingers were also found to be common sites of injury in musicians (Atunes & Moraes, 2012). These findings indicate that extensive playing time and/or unnatural posture from the position of a musical instrument can lead to both general and specific injuries to musicians at large.

For musicians, body position and posture are integral components to music-making. Musicians and their instruments must be, as noted by Atunes and Moraes (2012), analyzed for best postural alignments, ergonomics, and optimal positions of neck and hand. The long rehearsals that violinists and violists often sit through requires them to find appropriate body positions and frequently shift balance to maintain the best motor control possible during performances (Nymann et al., 2007). The most commonly seen injury, however, was found to be overuse (Fry, 1988). In the same review study conducted by Atunes and Moraes (2012), the conclusion reached was that in addition to overuse, focal dystonia and nerve compressions were the main disorders found, and that pain was the number one symptom. More specifically, Thoracic Outlet Syndrome was reported in 20% of the musicians studied, overuse in 50% of musicians, and focal dystonia in 10% of musicians (Foxman & Burgel, 2006). The repetitive movement of playing a musical instrument and poor posture from prolonged sitting and carrying instruments is thought to be the predominant contributor to these conditions (Moraes & Atunes, 2012).

The Alexander Technique

There are several treatment options available for musician injuries: preventative measures, occupational therapy, and mindfulness models such as the Alexander Technique all offer promising results. The AT offers musicians a method of changing their posture starting from a very basic level and allows those changes to transfer into the way a musician plays their instrument. This technique is a method of movement that is designed to bring heightened awareness to the way a person holds their body and aims to train the user to align their posture without unconscious or unnecessary muscular compensation.

The AT is described by authors Mayers and Babits (1987) as a re-training program to create mindfulness and to change inefficient movements that people make out of unconscious habit. The AT is not a stretching or relaxation technique such as yoga, nor a strengthening program such as Pilates, but rather a system of movement to promote efficient use of posture through using muscles embedded around the spine that are naturally designed to carry the head and back in an upright position. Throughout the course of a person's life, it is likely they will adapt to a pattern of movement that is unnatural but be unaware of their poor posture and assume their movements are normal and upright (Mayers & Babits, 1987).

There are three parts to the AT: developing an awareness of the physical state of the body, developing the ability to consciously refuse to respond to a situation with inefficient habits, and teaching a "direction" technique that communicates to the student how to use precise mental instructions to move the body with purpose and intention to maintain optimum balance of all body parts (Mayers & Babits, 1987). Peterson (2008) notes the biomechanical nature of the AT, relating that it zeroes in on the spine and skeleton, especially the cervical spine, and focuses on the most basic of movements. Even unconscious habits like standing up out of a chair are found to be fraught with potential physical problems when looked at more closely. In this research study, the use of the AT with the added ability to see in real-time how participant's posture responded through motion-capture technology has the potential to offer never-before-seen insights into the body mechanics of musicians.

Motion Capture Technology and Musicians

How then is it possible to detect postural imbalances that musicians themselves may not even recognize? Motion-capture technology, famous for its use in creating special effects for films, may offer a solution to this question. While studies have been conducted that observe a musician's performance through the use of motion capture technology, no studies have yet been pursued that focus on using this technology to detect and correct postural imbalances.

Motion-capture cameras allow researchers to detect postural changes musicians may experience as they play that would be nearly impossible to discern with the naked eye. This approach uses a system of cameras to track small, body-fixed markers that reflect near infrared light, allowing the cameras and computer software to "capture" the movements of these points on a musician's body to a high spatial resolution – within a few millimeters. Harnessing the capabilities of this technology offers the potential to definitively measure the movements of a musician and offer insight into developing tangible solutions for instrumentalists struggling with postural pain or imbalance.

Various exploratory studies exist on motion-capture technology and how it relates to studies with musicians. One study used the technology to measure the force of clarinetist's finger strokes (Palmer et al., 2009). Another study used motion-capture to track the movement of dancers and athletes and render still-frame images of what those motions looked like (Shan et al., 2010). An additional study researched the eigenmodes of music-induced movement to measure differences in joint movement when participants were asked to play an excerpt at three different speeds (Toivianinen, Luck, & Thompson, 2010). All studies used motion-capture cameras and reflective markers affixed to the participants to track the subject's movements.

Musician injury is an area of developing study, and while good sources are available for review, awareness in this area is not nearly as high as it is in the area of sports or other lifestyle activities that require fine motor movement or repetitive motion. The findings presented here give detail into the rationale of experiment parameters to include motion-capture software and the AT.

II. Purpose

The purpose of this study is to be able to identify the posture that musicians may experience firstly from their instructional experience, and secondly from a method such as the AT to observe and compare the postures of the violinist and violist participants by tracking specific anatomical landmarks (represented in **Figure 1**) with the motion-capture cameras to see if the AT training produced any measurable postural changes. The hypothesis proposes that the distance between the left jaw (mandibular angle) and left shoulder (acromion process) would increase after practicing the AT; this would indicate a lower, more relaxed position of the shoulder in relation to the chin. Similarly, it is hypothesized that the distance between the back, lower left head (occipital bone) and upper spine (C3 spinous process) would decrease following AT practice, further demonstrating a more relaxed playing position. A secondary hypothesis is that self-reported pain, tension, and focus would improve following AT practice.

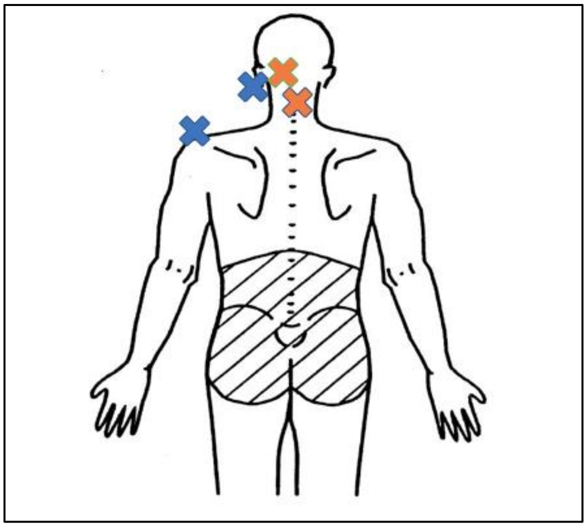

Figure 1: *Schematic showing location of anatomical reference markers used for measurement comparison. The blue set indicates the left acromion process and left mandibular angle. The orange set indicates the C3 spinous process and left occipital bone. In each set, the distance between the two markers was measured.*

III. Methodology

Participants

Participants for this research study were solicited either by email, mail, verbal invitation, or phone conversation. Fliers were posted and community music teachers were contacted to ask their students if they would be interested in participating. In order to join the study, the participant had to be at least 18 years of age, have had training of at least three years of music lessons in either violin and viola, and the ability to read sheet music. Exclusion criteria were professional musicians and any musicians who were currently experiencing intense pain due to their playing or another physical condition that could be exacerbated by participation. The reasoning for excluding professional musicians from the study was due to the research done by Rickert, Barret, and Ackerman (2015) who found that professional musicians tended to have already worked out the best posture for themselves as compared to student musicians who did not yet demonstrate a similar level of postural awareness.

Demographics

Participants were asked in a pre-AT questionnaire if their teacher has ever discussed the topic of injury, posture, and/or relaxation during formal lessons. Participants were also asked to give an overview of how much they played their instrument each week and how much, if any, pain they were currently experiencing. Height and age also were recorded.

Instrumentation

Motion-capture cameras and reflective markers were used to track the movement of participants in a motion capture lab. The University of Alabama in Huntsville (UAH) Autonomous Tracking of Movement (ATOM) Lab provided access to 33 Nexus Vicon T40s motion tracking cameras. The cameras were equipped with an Mx Giganet connectivity node as well as Nexus software, near infrared (NIR) strobes, and visible light filters to allow for operation under variable lighting conditions. These motion-capture cameras record the motion of small, bead-like IR-reflecting markers at 515 fps at a full resolution of 4 megapixels.

Procedures

Participants were asked to wear dark athletic clothing including fitted pants, a fitted, short sleeved t-shirt, and to have long hair tied back. Reflective markers were affixed to anatomical landmarks on the head, face, arm, back, and hip locations of participants with non-toxic craft glue dots and disposable, skin-safe Velcro strips, as seen in **Figure 2**. The first set of markers measured was placed between the C3 spinous process and left occipital bone, and the second set measured was placed between the left mandibular angle and acromion process.

Figure 2: *Photo of the author testing marker placements in the ATOM Lab during study development.*

The participants were encouraged to warm up on their instrument if they so desired before being tracked using the motion capture cameras to observe their movements as they played a simple etude that focused on producing continuous movement of left and right hands. Next, the participants were shown a video of the AT as it relates to a violinist or violist, recorded for the study by a local certified AT practitioner. Finally, the participants were asked to apply what they learned from the AT video and re-play the excerpts while being recorded again by the motion-capture cameras. A written questionnaire was completed before and after AT practice to ask participants to self-assess their own tension, focus, and pain levels on a scale of 1 – 10. A paired sample T-Test was used to analyze mean distances between two sets of reflective markers, and to compare pre- and post-AT self-assessment scores.

IV. Results

For this initial study, four participants were tested: three violinists and one violist. The average number of years playing was 12.0 years, and their mean age was 20.5 ± 1.3. Data are presented in **Table 1**. For the results collected, a Shapiro-Wilk test indicated data are normal. There was a statistically significant difference between the pre- and post-AT measurement of the mean distance between the reflective markers placed at the mandibular angle (M = 149.39 SD = 16.74) and acromion process (M = 154.16, SD = 18.88), (t = 4.36, p = .01). There was no statistically significant difference between the pre- and post-AT measurement of the mean distance between the reflective markers placed at the C3 spinous process (M = 117.96, SD = 17.08) and the occipital bone (M = 126.5, SD = 11.36), (t = 2.02, p = .30). However, the mean distance was larger in three of the four participants.

For the questionnaire, tension, focus, and pain were all ranked on a scale of 1 – 10. Data are presented in **Table 2**. There was no statistical difference in tension, focus, or pain. **Figure 3** presents a computer model of a marker placement test. See also **Figures 4, 5, 6, and 7** for data charts representing the XYZ axis differences in pre- and post-AT tests for both marker sets from a participant.

Table 1: *Comparison of the distance between reflective markers pre- and post-Alexander Technique*

Marker placement	**Pre-AT** **M ± SD**	**Post- AT** **M ± SD**	**t**	**p**
Mandibular Angle and Acromion Process	149.39 ± 16.74	154.16 ± 18.88	4.36	.01
C3 Spinous Process and Occipital Bone	117.96 ± 17.08	126.5 ± 11.36	2.02	.30

Note. Distance was measured in mm. A paired samples T-Test was used to analyze data over a 10 - 60 sec time period during the instrumental playing.

Table 2: *Self-Questionnaire results from participants in pre- and post-AT tests*

	Pre-Test Tension	**Post-Test Tension**	**Pre-Test Focus**	**Post-Test Focus**	**Pre-Test Pain**	**Post-Test Pain**
Participant 03	4	4	8	8	3+	3
Participant 04	4	1	6	9	2	2
Participant 05	2	2	7	5	1	1
Participant 06	1	1	6	6	1	1

Note. Tension was measured on a scale of one (lowest) to 10 (highest). Focus was measured on a scale of one (poor) to 10 (excellent). Pain was measured on a scale of one (no pain) to 10 (highest pain).

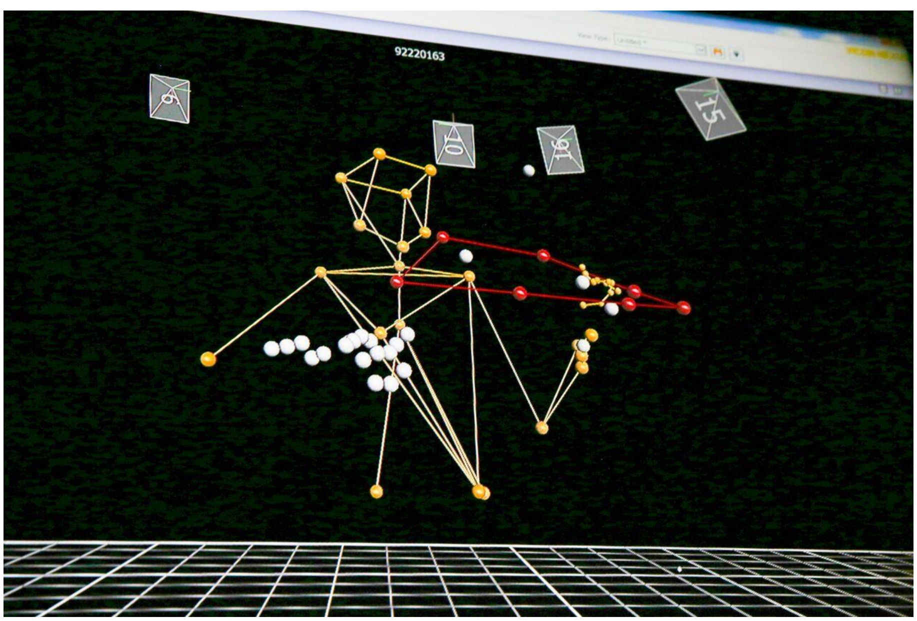

Figure 3: *Computer rendering of the author testing reflective marker placement and camera angles. Each dot represents a reflective marker, with the yellow dots indicating anatomical landmarks and red dots indicating the violin. The numbered boxes in the upper part of the photo indicate placement of some of the motion-capture cameras.*

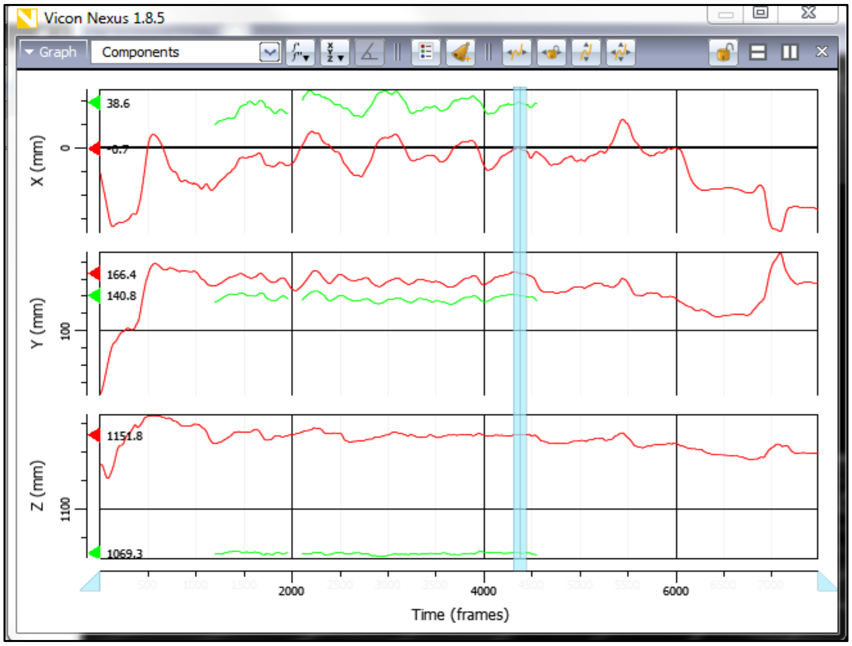

Figure 4: *Sample view of computer software showing XYZ axis of movements between the C3 spinous process and left side of the occipital bone showing approximately thirty seconds of playing time from Participant 1, Trial 1. The green line shows the C3 spinous process and the red line shows the left side of the occipital bone.*

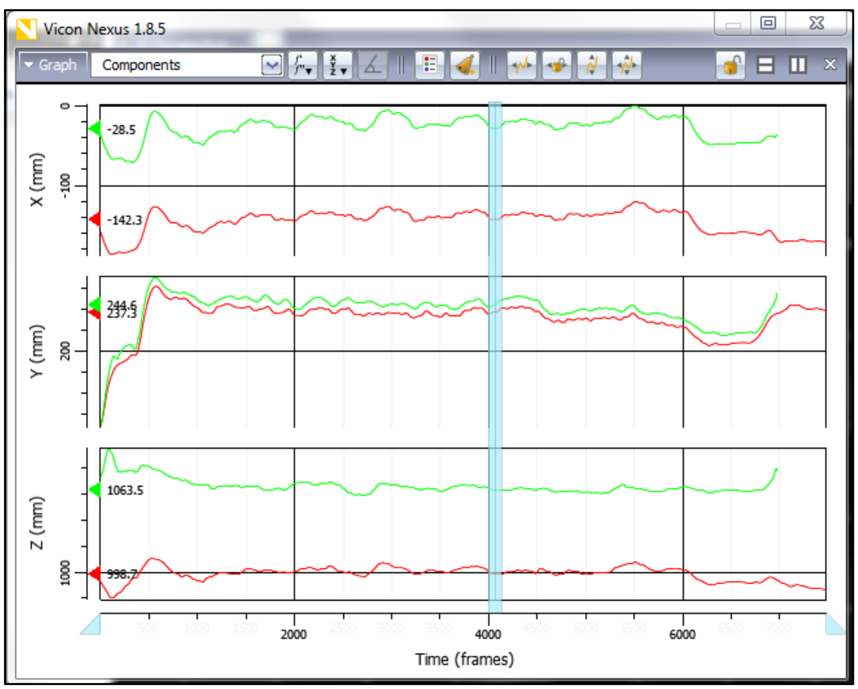

Figure 5: *Sample view of computer software showing XYZ axis of movement between the left mandibular angle and left acromion process showing approximately forty seconds of playing time from Participant 1, Trial 1. The green line shows the left mandibular angle and the red line shows the left acromion process.*

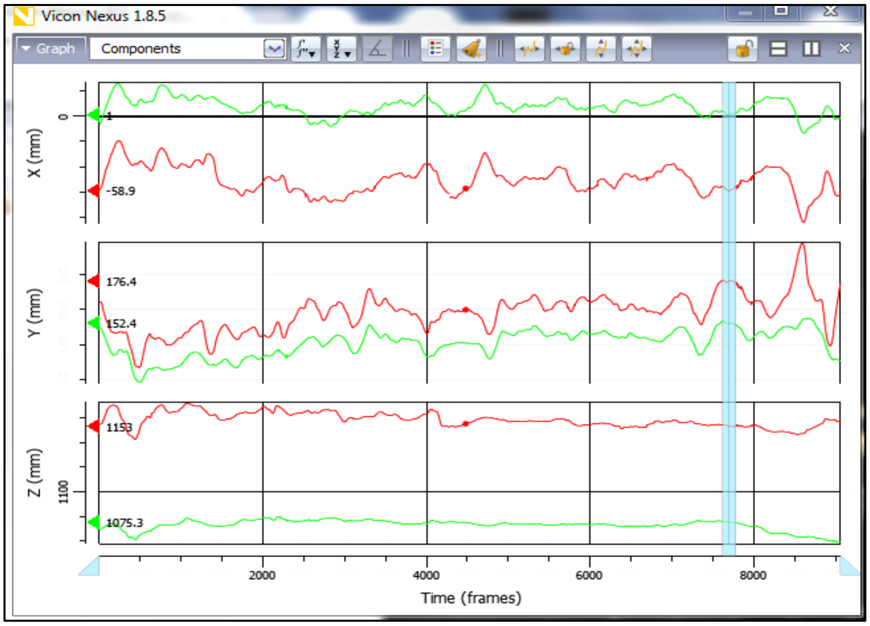

Figure 6: *Sample view of computer software showing XYZ axis of movement between the C3 spinous process and left orbital surface showing approximately forty seconds of playing from Participant 1, Trial 2. The left orbital surface is in red and the C3 spinous process is in green.*

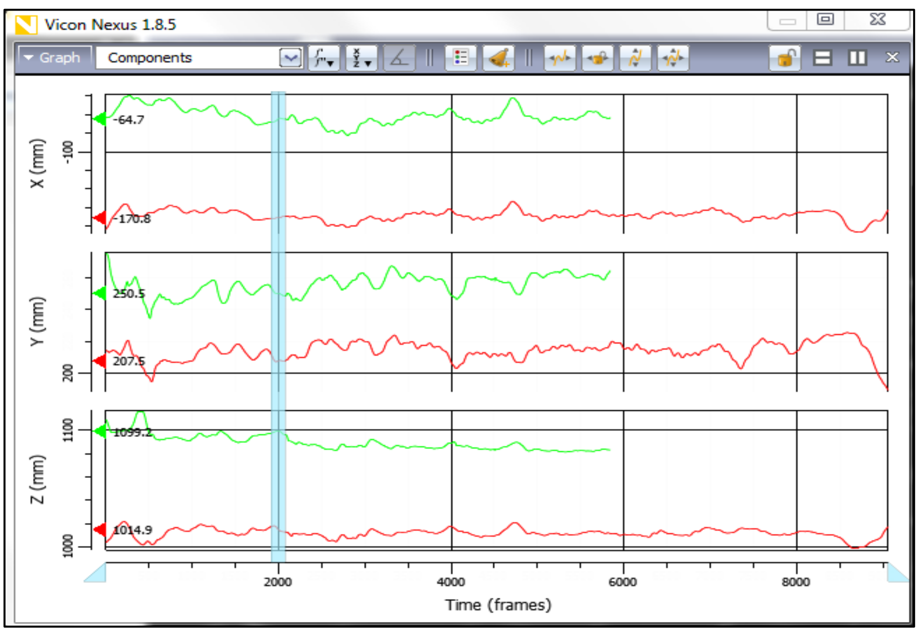

Figure 7: *Sample view of computer software showing XYZ axis of movement between the left mandibular surface and left acromion process showing approximately thirty seconds of playing from Participant 1, Trial 2. The left acromion is in red and the left mandibular angle is in green.*

V. Discussion

Musician injury is an issue that often goes unspoken or ignored by instrumentalists. This can be particularly true for student musicians who do not have the experience or training necessary to fully understand healthy practicing methods. The research demographic of this study focused on student musicians due to the higher likelihood they have of ignoring ongoing pain and tension signals. Professional and career musicians do sustain injuries due to their high volume of playing, but are more likely to seek out treatment when injuries do occur. Conversely, students can become trapped in cycles of physical damage and overuse (Rickert et al., 2015). Finding a reproducible way to reduce tension and pain in student musicians has the potential to help teach the awareness that professional-level musicians have at a much earlier stage for the student musician.

The AT was chosen as the tension-reducing method due to its gentle approach and prevalence as a treatment routine among musicians. Because the AT focuses on elongating the neck and spine by engaging muscles embedded around the backbone, it has potential to move participants out of poor postural habits. Applying AT methods allows the user to align their body into a more natural position and combat the effects of holding a violin or viola—which often require a musician to tilt and compress their head, neck, shoulders, and arms into unnatural positions.

The hypothesis that was developed for this research study theorized that practicing the AT would reduce tension and pain in violinists and violists by bringing them into a more relaxed and ergonomic alignment. Through the AT, it was hypothesized that more distance would be created between the left jaw and shoulder (left mandibular angle and left acromion process) markers if tension was reduced, which would allow the muscles in that area to relax and "let down." The hypothesis for the back-left head and spine (left occipital bone and C3 spinous process) marker set was that there would be less space between these markers if the AT reduced tension coming from the downward pressure of the head, allowing the head to rotate upwards slightly from the chin.

Results indicated that the measurements between the left mandibular angle and left acromion process were statistically different, indicating an increase in length between the two markers. The comparison criteria hypothesized that there would be an increase in length between these points if the AT either reduced the amount of compressed, downward pressure the musician was placing onto their instrument from the chin, or alternatively if the amount of upward pressure the participant was producing from the shoulder to lift the instrument was decreased.

Results for the C3 spinous process and occipital bone were not statistically different. However, there was a change as the mean distance between the two markers was longer. The comparison criteria hypothesized that the AT would shorten the distance between those two points, however the opposite occurred in three out of four tests.

Results of the study proved the hypothesis to be true with the marker set on the left mandibular angle and left acromion process: there was a statistically significant increase in the distance between the two markers after the participants watched an instructional video on the AT. This would indicate that the left shoulder most likely dropped due to either increased awareness or a state of greater relaxation.

The reason for measuring the distance between the jaw and the shoulder was to determine if some of the compression in the head and neck area of violinists/violists could be reduced. The constant turning, dropping, and holding of the jaw to the instrument has the potential to cause injury, especially if the musician is also lifting their left shoulder to create more stability. The AT, particularly if combined with a customized chin rest or shoulder rest fitted to a violinist's/violist's neck length could reduce tension that is commonly experienced, but not often noticed.

The hypothesis was not proven in the marker set placed on the occipital bone and C3 spinous process. In three out of four tests, there was a greater amount of space between the markers rather than a lesser amount of space. Measuring the distance between the back-left head and upper spine was chosen because a violinist's/violist's head can tend to be pressed down onto the instrument, particularly if the chin or shoulder rest are too short for the musician's neck. The thought process behind this hypothesis was that relieving tension in this area would allow the head to not be as forcefully pressed into the instrument, raising it and shortening the distance between the markers. However, this did not consider the fact that the chin rest height was not changing during the testing so it was relatively impossible to shorten the distance between the marker set (as there was no way that the participant's head could come up without using the shoulder to raise the instrument in compensation). Therefore, the results seen may be due to the focus that the AT has on lengthening the spine, which would create greater space between those two areas. This would send non-corroborative results over the original hypothesis that it would prevent the head from dropping unnecessarily.

The self-questionnaire was given to allow the musicians to assess themselves on what the process with the AT felt like to them. The scaled questionnaire ranking tension, focus, and pain from 1 – 10 allowed a ballpark estimate of how they perceived each of these elements and how the AT affected them. Overall results show a variety of response. None of the participants experienced an increase or decrease in pain (if any was present). Nearly all the participants indicated better focus after watching the AT lesson as opposed to before. Three participants rated their tension levels as staying the same, and one participant rated less tension post-AT lesson.

Three of the participants reported that they had either experienced pain/discomfort in the past or were currently experiencing pain in the present, although not to an extent they had stopped playing. One participant was actively seeking physical therapy for their pain. It must be pointed out that it is important to encourage students to be verbal about pain or discomfort they may be experiencing while playing. In a research survey of college cellists, authors Rickert et al. (2015) reported that the student cellists they interviewed showed poor awareness of how to respond to the pain and tension they were actively experiencing, instead shrugging it off and continuing in practice patterns that would ultimately be damaging to their health. In contrast, the professional musicians that the researchers interviewed demonstrated a much higher awareness of how to pace themselves and be more conscious of when their bodies were showing signs of overuse (Rickert et al., 2015).

The participants who reported experiencing pain in this study did show active awareness of it, but did not always know why it was happening or how to combat it. This is relevant to this study because so many of the injuries—especially overuse injuries—that student musicians develop could potentially be prevented or offset with better awareness and self-disclosure of pain to seek treatment options. Therefore, there are two fronts that musician injury must be fought on: creating awareness and then finding a diagnosis and viable treatment plan.

The participants were provided the opportunity to write down their overall thoughts on the experience after the testing was complete. A common theme from this feedback was that the participants could see potential in the method for reducing tension and noticed a difference either in the way they were thinking about their playing or the way it felt. However, three of four of the participants indicated that the short instructional video was not enough to produce a significant or lasting change.

Conclusions

The overall conclusion of this study is that the AT does have the potential to influence the amount of tension that violinists and violists experience and enhance relaxation and awareness levels. There was no significant indication that the AT could change pain levels. Some limitations that the study faced were a lack of participants due to the specific demographic tested (non-professional musicians over the age of 18). Another constraint was that the study was unable to offer more than a short instructional video on the AT.

Considerations for future research in this area would be to offer a more in-depth AT experience for participants as preliminary data indicates that a one-on-one live session with an AT practitioner and participant would give clearer testing results. An improved experiment design could provide the additional data needed to confirm and expand on these initial results For example, an eight-week randomized control trial could be performed where half the participants were trained in AT methods while the other half practiced as normal. Additionally, further recommendations for future research would be to expand measurements to include biological indices (heart rate, blood pressure, results of additional test sessions) with a larger sample of participants.

VI. Acknowledgments

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References

Ackerman B., & Chan, C. (2014). Evidence-informed Physical Therapy Management of Performance-related Musculoskeletal Disorders in Musicians. *Cognitive Science*. 5(706)

Foxman I. & Burgel B.J., (2006). Musician Health and Safety: Preventing Playing-related Musculoskeletal Disorders. *AAOHN J.* 54(7), 309–16

Fry, H. J. (1988). The Treatment of Overuse Syndrome in Musicians. Results in 175 Patients. *J R Social Medicine.* 81(10), 572 – 575

Hagberg M, Thiringer G, Brandström L. (2005). Incidence of Tinnitus, Impaired Hearing and Musculoskeletal Disorders among Students Enrolled in Academic Music Education: A Retrospective Cohort Study. *International Archives of Occupational and Environmental Health.* 78(5), 75–83. PUBmed.

Lukomski, L. (2004). Common Injuries of Musicians. Honors Thesis. Paper 1635.

Mayers, H., & Babits, L. (1987). A Balanced Approach: The Alexander Technique. *Music Educators Journal.* 74(3), 51 - 54. JSTOR. Web.

Moraes, G.F.S. & Atunes, A.P. (2012) Musculoskeletal Disorders in Professional Violinists and Violists. Systematic review. *Acta Ortopedica Brasil.* 20(1), 43 - 47.

Nyman T., Wiktorin C., Mulder M., & Johansson Y.L., (2007) Work Postures and Neck-shoulder Pain among Orchestra Musicians. *American Journal of Industrial Medicine*. 50(5), 370–6

Palmer, C., Koopmans, E., Loehr J.D., & Carter, C. (2009). Movement-Related Feedback and Temporal Accuracy in Clarinet Performance. *Music Perception: An Interdisciplinary Journal*. 26(1), 439 – 449. JSTOR. Web.

Peterson, P. (2008). On the Voice: Alexander or Feldenkrais: Which Method Is Best? *The Choral Journal,* 48(11), 67-72.

Rickert, D. L. L., Barret, M. S., & Ackermann, B. J. (2015) Are Music Students Fit to Play? A Case Study of Health Awareness and Injury Attitudes amongst Tertiary Student Cellists. *International Society for Music Education*. 33(4), 426 - 441.

Shan, G. Visentin, P. and Harnett, T. (2010). A Novel Use of 3D Motion Capture: Creating Conceptual Links between Technology and Representation of Human Gesture in the Visual Arts. *Leonardo.* 43(1), 34 - 42, 17.

Toiviainen, P., Luck G., & Thompson, R. (2010). Embodied Meter: Hierarchical Eigenmodes in Music-Induced Movement. *Music Perception: An Interdisciplinary Journal.* 28(1), 59 – 70.