Comparative Analysis: An Assessment of Posture and Muscle Activity in Trumpet Players Using Motion Capture and Electromyography

Ricardo Vela, Ben Dufour, David Saul and George Sarkodie, 2020

Introduction

Trumpet players experience musculoskeletal problems that may be dependent on the biomechanical demands associated with the type of music performed. For example, a trumpet player in a concert setting would typically sit, while trumpet playing in a marching band setting involves complex lower body choreography. These differences suggest differences in postural and biomechanical loading and differential levels of risk for musculoskeletal injuries. Unfortunately, there are no known studies that characterize these differences.

The purpose of this pilot study was to examine and compare posture and muscle activity patterns associated with playing trumpet in simulated concert band and marching band settings. Specific aims included the comparison of cervical and lumbar postures and the activity of posterior stabilizer muscles.

Previous research indicated that brass players experience pain while participating in both concert and marching rehearsals, however pain was reported to be greater in marching rehearsals than in concert rehearsals. A previous study reported that pain in brass musicians is twice as prevalent during marching band rehearsal than non-marching related playing (Hatheway and Chesky, 2013). A study on pianists used motion capture technology to examine posture during performance. This study found that posture is an important factor in the prevention of playing-related musculoskeletal disorders for pianists. (Shamoto, 2013). There is currently no research focused on the differences of cervical and lumbar posture between marching and concert in trumpet players using motion capture technology.

Methods

To establish proof of concept, one subject was guided to the motion capture setup area where they had markers and sensors placed on their body based on the marker template map. A list of the complete marker set, categorized by function, as well as an image of the marker set placed on a subject is shown in *Table and Image 1*. The cervical markers were used to calculate the neck angle and the spinal markers were used to obtain the variance in spinal curve throughout the trials.

Marker No.	**Cervical Markers**	**Marker No.**	**Spinal Markers**
1	**External Occipital Protuberance (EOP)**	**1**	**T4**

2	**C1 (Atlas)**	**2**	**T7**
3	**CLAV(Clavicle)**	**3**	**T12**
		4	**L2**
		5	**L4**
		6	**Sacrum (SACR)**

Table 1. Complete Marker Set

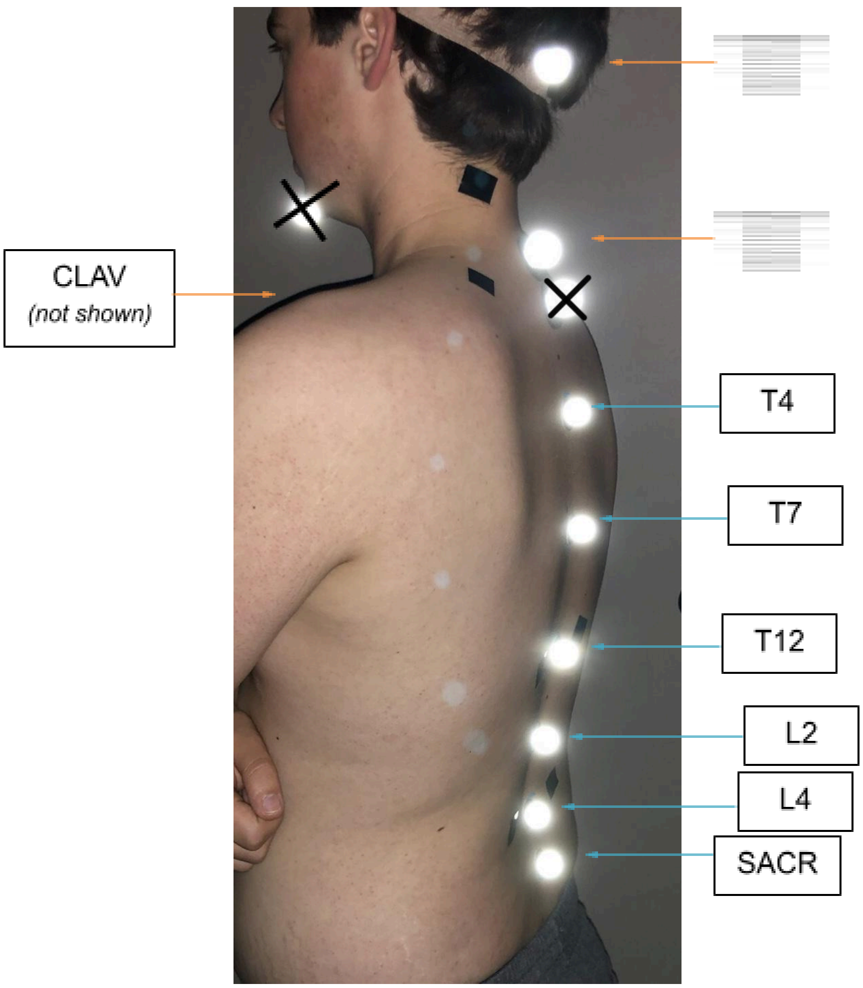

Image 1. Marker Set as placed on subject; "X" marker was omitted

The standard anatomical posture measurement was used as reference during placement. The participant had the EOP marker placed on their head with a non-adhesive bandage. The rest of the markers were placed on the participant with skin-friendly adhesive tape. Afterwards, a covered trumpet was handed to the subject to use for the duration of data collection. Subjects were instructed to perform different concert and marching stances and basic tasks within the motion capture area (*Table 2)*. These trials reflected everyday activities that trumpet players perform for long periods of time in a practice or performance setting. There were six different trials as shown in the table below. Abbreviated names were included to organize and simplify the file naming process. It is important to note that sitting or standing normally may slightly differ from their "ready" stance. The ready, or "at attention", stance refers to the position the musician takes when performing but not necessarily playing. Musicians briefly take this stance prior to the start of a performance. Both were included, even though they may be similar, to assess how holding the trumpet changes posture.

Stance	Abbreviated Name	Task
Concert	C1	Sitting without Trumpet; Concert Control
Concert	C2	Sitting with Trumpet in Playing Position, No Playing
Concert	C3	Sitting with Trumpet while Playing
Marching	M1	Standing without Trumpet
Marching	M2	Standing with Trumpet, Marching Stance, No Playing
Marching	M3	Marching with Trumpet while Playing

Table 2. Trials for each participant and their respective shorthand

Participants were either playing or holding a trumpet in playing position. The length of each trial was 15 seconds. After the participant finalized their trial, the data was "cleaned-up" in post process using the Cortex software. This "clean-up" includes any discontinuities, marker errors, or missing markers. Errors were restored, if there were no major discontinuities, using functions such as cubic join, marker ID, or smoothing. The trial needed to be trimmed if a marker is constantly missing for a longer period of the data collection.

After the data was cleaned in post process, the data was exported into a .TRC file. This file was opened in excel and showed the x,y, and z positional coordinates for each marker in each frame. Using an excel exporting feature, the data file was export into MATLAB and organized into columns where each marker was saved as a 3D point in space for each frame using arrays in MATLAB. Although some of the information was readily available within the Cortex application, MATLAB is a more computationally viable option where more complex calculations and application-based functions are achieved.

To calculate the cervical angle, a for loop in MATLAB was created that encompassed all frames for the duration of the trial. Within the for loop, the x,y, and z columns for each cervical marker (EOP, C1,CLAV) were imported into the workspace. Using the 3D distance formula, the distance between markers EOP & CLAV as well as CLAV & C1 were calculated. The law of cosines was used to find those two distances and the neck angle can be calculated for each frame using the for loop. The last step was to plot these angles over time (frame number vs neck angle) for each of the six trials.

$$\text{3D: } distance = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}$$

Formula 1. Distance Formula

$$\cos A = \frac{b^2 + c^2 - a^2}{2bc}$$

Formula 2. Law of Cosines Angle Formula

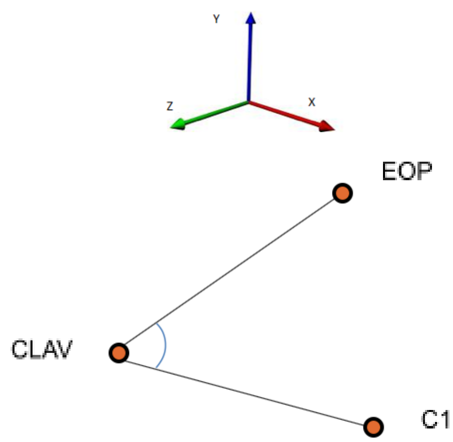

Figure 1. Cervical angle using 3 markers (sagittal view)

The process of obtaining the curve on the thoracic/lumbar region of the spine is similar in terms of exporting data from Cortex and importing into MATLAB. The process also used a for loop that ran through all frames, used the same excel data extracting process, and used the same MATLAB importing feature. The difference is that only the thoracic/lumbar spinal markers are used. Interpolation for a curve with only five markers would be inaccurate so a geometric approach was used to find a more accurate representation of curvature difference. The diagram below shows the geometric theory behind the rationale.

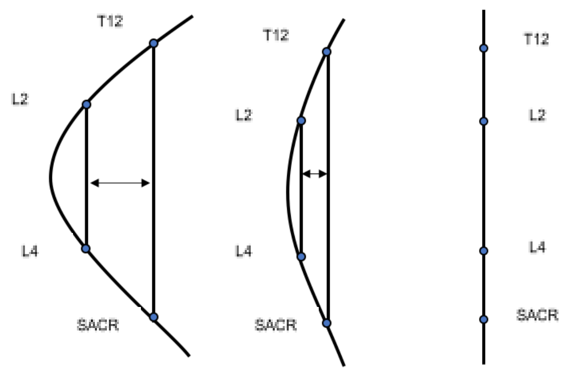

Figure 2. Geometric theory behind obtaining spinal curvature; Distance decreases left to right

The line on the right represents the 3D imaginary line made between T12 and SACR and the shorter line on the left represents the 3D line made between L2 and L4. When the spine exhibits a larger radius of curvature, as represented with the exaggerated curve, the lines would be further separated, increasing the distance between the imaginary lines. Theoretically, if there is no curve, the distance between the lines is zero, as seen in the right graphic. Using the x,y, and z coordinates of spinal markers T12 & SACR, a 3D vector was created that passed between those two points. The same process was done for markers L2 & L4. The line normal to the midpoint, obtained using the cross product, of the left line was extended to the midpoint of the right line. This distance served as accurate representation of the degree of curvature on the spine. This change in distance would be sufficient enough to compare change in curvature.

Results

Due to COVID-19, the results were based on available data as of March 4th, 2020. *Figure 3* shows two trials: Marching while Playing (abbreviated M3) and Sitting while Playing (abbreviated C3). It is evident that M3 had a larger variance, due to motion caused by marching, but also a higher overall distance, and therefore curvature, with an average distance around 140 mm. In return, C3 had less variance, due to less swaying motion, with an overall average distance of about 20 mm. The average difference between M3 and C3 was about 120 mm.

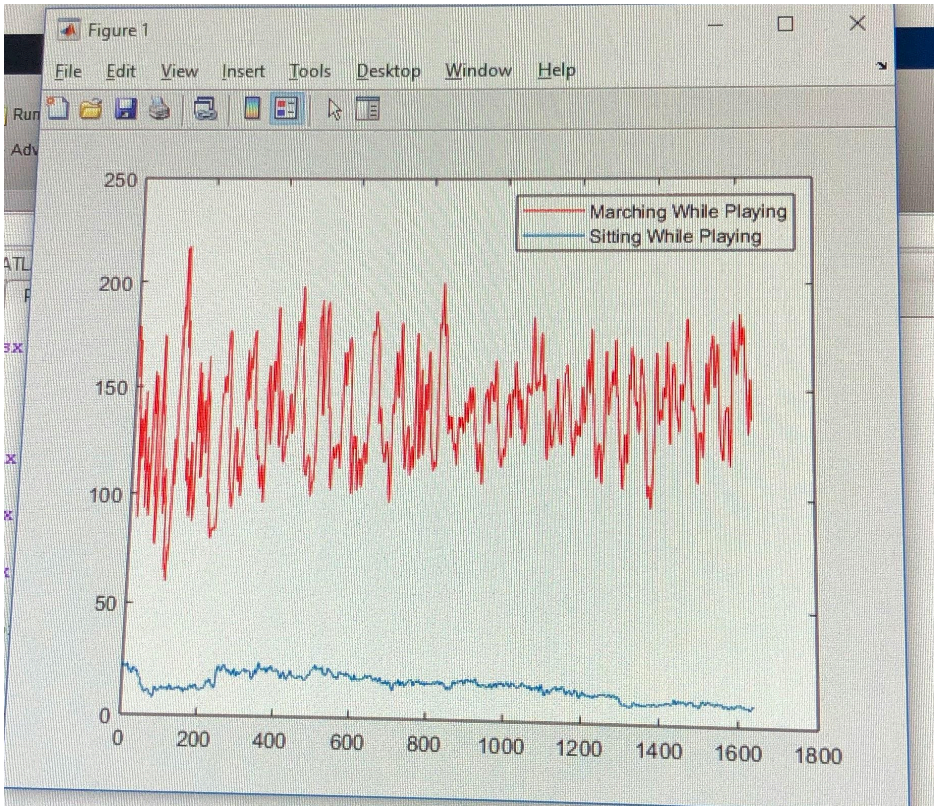

Figure 3. Marching vs Concert while playing comparison

Discussion

Although full trials could not be carried out due to COVID-19, pilot data from one team member was collected and analyzed based on our methodology above. The methods in this paper would, in theory, be sufficient enough to calculate, analyze, and provide the appropriate data for any trumpet player. The only data available to report is the thoracic/lumbar spinal curvature for two trials: Sitting while Playing (C3) and Marching while Playing (M3). These trials were the first to be "cleaned" in post-process since we hypothesized the largest difference would be between C3 and M3. Cervical angles could not be reported due to the chin marker not showing up for more than half the trail. Post-process corrections were attempted but marker tracking was beyond repair. Our next step was to "clean" the remaining test trials, but meeting in the lab was no longer an option due to COVID-19.

Originally, there was a larger marker set (many used as reference points) but not all markers were detected, mostly due to the limitation of space in the testing area. Since twice as many markers were used, a large amount of overall data was produced, which wasn't necessary for our pilot study. The testing area needed to be optimized to where the highest and lowest marker always appeared in the frame. There was an issue during the test run where the mental protuberance, or chin, marker did not show for much of the trial. For that reason, we decided to lower the marker from the chin to the clavicle to ensure the marker is always in frame (*Figure 1)*. We also planned to use the CLAV marker instead of the marker on the chin in the next round of testing which, unfortunately, could not be carried out.

In terms of available data reported in this paper, we can only report the difference in the lower spinal curvature between Sitting while Playing and Marching while Playing. These two individual trials had no thoracic or lumbar marker issues during the data recording or during post-process. *Figure 3* shows how Marching while Playing (red line) clearly has a higher average distance than Sitting while Playing (blue line) of about 120 mm. This distance, as explained in *Figure 2*, can be directly correlated with the amount of curvature of the lower spine. The correlation between the distance and the curvature implies that the body has a higher average curvature when Marching while Playing compared to that of Sitting while Playing. The larger variance in the Marching while Playing is due to the swaying movement of the body. While this sample alone cannot be used to concretely conclude any results, the proof of concept has been shown for a future pilot study.

Future Implementation

Although this pilot study could not be completed due to factors out of our control, the methodology is comprehensively laid out and the methodology is functional, at least in one instance. Given that process is similar for all trials, we are confident that this pilot study can be concluded in the near future. It is also worth mentioning that this study was approved by the IRB (IRB-20-45) for human testing.

Although our testing samples yielded some important data for validation, it is also important to note what task did not work as we expected. The main issue was calibrating to correctly optimize the testing area. Correct calibration took at least 10x longer than expected due to issues with the cameras and software. We highly recommend referencing our step-by-step procedure that outlines calibration, creating a marker set, and post-process operations for the Cortex software. We also recommend contacting Cortex support if any technical difficulties occur to quickly solve any software-related issues. Another issue was had, as mentioned previously, was moving the marker on the chin lower to the clavicle. We realized that the clavicle is far more stationary than the chin which would lead to less angle variation during the performance. Testing on ourselves helped solve some errors that we would not have foreseen otherwise.

Other issues we anticipate have to do with logistical errors. This includes software issues with Cortex including unexpected closures, issues with a small testing area, and markers not showing up for an extended period of time. Since there is a large amount of data imported into MATLAB, there might be timeout errors as well. We recommend using a CPU that can handle large amounts of code or reducing the time for each trial.

For future implementation, we would like to develop a formula that relates the distance between the lines created by the four markers to the actual spinal curve with respect to the sagittal plane. We believe this could be a more efficient and comprehensive way to report our values overall. In terms of reporting the motion capture of the thoracic/lumbar spinal curve with our current method, we recommend using a box and whisker plot showing data for each trial in every stance. We also recommend organizing all the data for each participant individually to more clearly see the difference between participants, not as a whole. EMG data should be synchronized with the motion capture data and reported as RMS graphs for each individual. ANOVA analysis would be an appropriate way to analyze the EMG data.

Electromyography was also incorporated into this project further into the semester since posture is largely influenced by stabilizer muscles. The following EMG stabilizer muscles were targeted using the 6-electrode DELSYS system. EMG data would be reported as root mean squared graphs. The graphs would be compared to see if there are any significant differences between graphs. An electrode placement map is also shown (represented by the black tape).

Electrodes	Muscle	Interest
1 & 2	Splenius Capitis	General neck movement
3 & 4	Latissimus Dorsi	Major stabilizer muscle
5 & 6	Erector Spinae (Lumbar Region)	Specific to motion capture area of interest

Table 3. Electrode placement for EMG

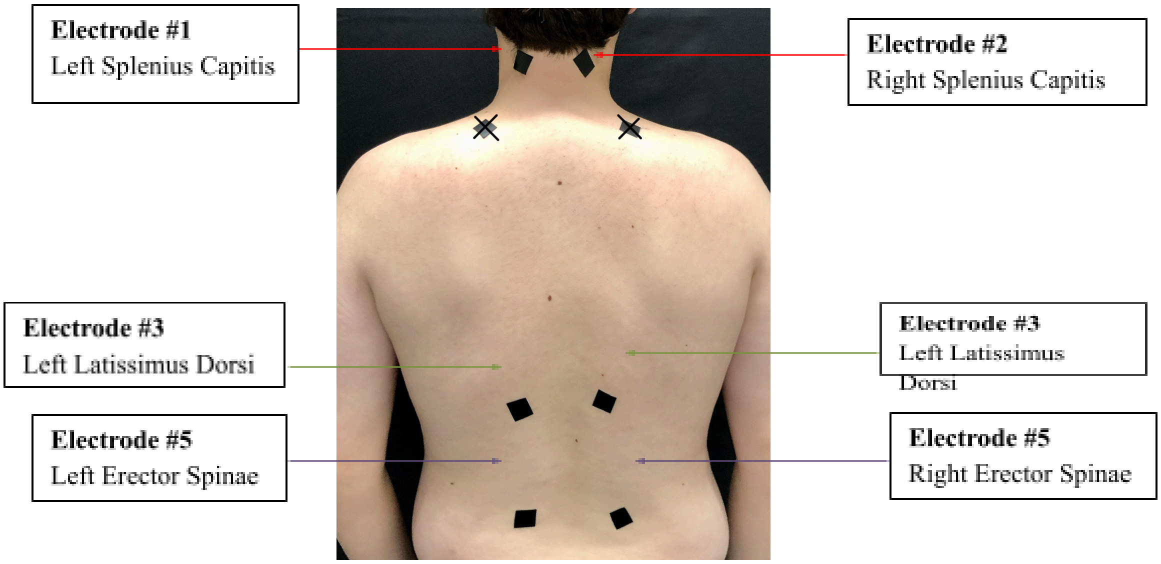

Image 2. Electrode placement; "X" electrodes omitted

Overall, we would like to thank Dr. Patterson and Dr. Chesky for the constant support with this project. We are glad we have continued a research project between College of Music and the College of Engineering for several years. We look forward and are excited to see the results of this study in the future.