University of Nevada, Reno

Head Position Variability During Single and Dual-task Tandem Gait Concussion Testing Protocol

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science

in Kinesiology

by

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ABSTRACT

The tandem gait (TG) test is commonly administered to evaluate and diagnose possible sports-related concussions. To date, head position is not controlled for, nor has its potential influence been studied during TG testing. **PURPOSE**: Examine the difference in the mediolateral (ML) sway and velocity and time to complete between two head positions of cervical neutral and cervical flexion during single and dual-task tandem gait. **METHODS**: 25 apparently healthy subjects (age=21.9±1.41 years) performed tandem gait walking along a 3-meter piece of tape affixed to an instrumented walkway (30 Hz, Tekscan Strideway, Tekscan Inc., South Boston, MA). Each participant completed 3 randomized trials of 2 different head positions, cervical neutral (CN) and cervical flexion (CF). The time to complete and center of pressure (COP), filtered using empirical mode decomposition, were measured during the tasks and analyzed by the 1st pass (FP), turn (T), and 2nd (SP) using a custom MATLAB code. The time to complete the task and average mean excursion in the ML direction, velocity in the ML direction, were ensemble averaged and compared using a repeated measures ANOVA. **RESULTS**: A significant difference was found for single-task FP mean excursion ML (CN=1.78±0.54cm, CF=1.49±0.38cm; p=0.007), SP mean excursion ML (CN=1.72±0.44cm, CF=1.53±0.39cm; p=0.03). A significant difference was found for dual-task FP mean excursion ML (CN=1.80±0.37cm, CF=1.52±0.40cm; p=0.002), SP mean excursion ML (CN=2.00±0.50cm, CF=1.58±0.34cm; p<0.001), and T mean excursion ML (CN=2.81±0.80cm; CF=2.29±0.58cm; p=0.004) by head position. There was no

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significant difference was found in single-task or dual-task trials in the ML velocity or time by head position. **CONCLUSION**: The results of this study suggest that during a fixed head position of CN during dual-task TG, the COP ML sway increases during the FP, SP, and T when the participants are unable to look around. Secondly, there is an increase in COP ML sway during single-task TG when controlling head position. This research provides preliminary evidence that fixed head positions may alter the clinical application of concussion TG testing.

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DEDICATION

I dedicate this thesis to my family. Weston, thank you for your love and never-ending support in all of my endeavors. To our son Oliver, you were with me from the beginning of this process to the end. Everything I do is for you.

Contents

INTRODUCTION

Concussion is often used in the medical literature as a synonym for mild traumatic brain injury (TBI), but it probably more accurately describes a subset of milder brain injury.[1] As of 2019, the Center for Disease Control (CDC) estimates that 223,135 hospitalized traumatic brain injuries were sustained in the United States, and as many as 3.8 million sport-related TBIs occur annually; the vast majority of TBIs that occur in sports are commonly assessed as concussions.[2–4] Some have suggested the term "head injury" should be used to infer pathophysiology, while the term concussion should be used to describe the symptoms and impaired functional status following some type of head trauma because impairments are present in the absence of detectable structural damage.[1,5]

While the definition of a concussion, sport-related or not, has changed over the years, as recently as 2017 the Concussion in Sport Group (CISG) has defined a concussion as "…a TBI induced by biomechanical forces".[1] Several common mechanisms that may be used to define a concussive injury may include a direct blow to the head, neck, or face, a force on the body that is transmitted to the head, rapid onset of short-lived symptoms that can resolve spontaneously, a range of clinical symptoms that may or may not include loss of consciousness, and presence of clinical symptoms with no significant abnormalities observed with neuroimaging tests.[1] While concussions can be sustained during regular activities and accidents, for the purpose of this paper, concussions will be referred to as a response to a blow to the head sustained by an adult between the ages of 18 and 25 years old during a sport-related event or activity, also known as a Sport-Related Concussion (SRC).

Symptoms commonly associated with concussions include noise and light sensitivity, headaches, nausea or vomiting, foggy or groggy feeling, cognitive issues, anxiousness, difficulty with short or long-term memory, and balance and postural control deficits.[1,6,7] The SCAT-5 was recently updated from the SCAT-3 to include tests for impairments commonly associated with balance and postural control such as the modified balance scoring system (mBESS) and tandem gait.[8–10] The SCAT-5 is commonly administered between ten minutes and two days after a suspected SRC because the diagnostic utility and reliability diminish three to five days postinjury.[10] These tests are clinically accepted as the method of diagnosis for a concussion as CT or MRI scans may show negative results in the presence of the clinically accepted diagnostic symptoms.[1]

While there is currently no widely used gradation scale of severity employed, the Glasgow Coma Scale (GCS) or the Glasgow Outcome Scale (GOS) have been proposed as a method of classification for the severity of an SRC.[1] The GCS suggests a score of 8 or less is a more severe injury, 9-12 is a moderate injury, 13-15 is a mild injury, and anything over a score of 15 is considered less severe.[1] Typically, a clinically diagnosed concussion would be categorized as a mild injury within the GCS with a score of 13-15.[1] The GCS remains the most widely used classification for TBIs, even though it is not specific to concussions.[1] In the past, the terms “mild”, “moderate”, or “severe” were used and based on any loss of consciousness and its duration.[1]

One of the commonly reported symptoms of a concussion is dizziness, which in turn affects postural sway, or excursion, stemming from alterations in mental and motor status due to system impairments.[11] To maintain an upright stance, the effect of gravity must be countered with corrective torque by the feet against the support surface through feedback control in the mediolateral and anteroposterior direction.[12] In Winter 1998, it was proposed that an inverted pendulum model relates to the controlled variable of the center of mass (COM) with the center of pressure (COP) and suggests the central nervous system (CNS) dictates the muscle tone for balance control against large inertial loads within the gravitational forces that might attempt to influence the inverted pendulum.[13] Recently, Murray et al., 2021 suggests that concussed individuals have an increase in mediolateral (ML) sway over a healthy population while performing the SCAT-5 tandem gait concussion protocol assessment.[14]

Field Tests and Tandem Gait

Field and clinical tests are commonly administered to evaluate and diagnose probable concussions and determine whether an athlete can return to play.[10] One such test commonly administered is Tandem Gait. Tandem gait tests are administered by having the patient walk along a 3m tape on the floor where the heel and toe of the opposing foot touch on each step.[8] Smaller net sway variability of COP during normal gait suggests better postural control and a shorter completion time.[6,15] While many studies have looked at the efficacy and reliability of tandem gait testing, to date, head posture during tandem gait has not been studied or controlled for clinically, especially when 2.6% of all clinical encounters report dizziness, where dizziness is a common complaint associated with concussions.[16]

Vestibular Impact on Gait

To control upright posture, humans use a multimodal integration of sensory information.[17] During normal gait locomotor efference was previously thought to be predominantly governed by sensorimotor reflexes.[18] Currently, it is understood that walking utilizes the combination and integration of visual, somatosensory, and vestibular input.[15,19] Notably, when the somatosensory modality is isolated, the body is unable to differentiate between the movement of the support surface and the movement of the body.[15] When healthy subjects stand on a platform, the sensory feedback consists of 70% somatosensory input, 20% vestibular, and 10% visual.[12] However, when the platform oscillates, the input switches to 70% vestibular, 20% visual, and 10% somatosensory input.[12] In patients with bilateral vestibular disorders, when asked to walk in light conditions, the range for the angular head position was found to be between 70°-100°, where 90° is the horizon, compared to normal patients who were found to be between 89 ± 2° for the angular head position.[20] The range increased when walking in darkened conditions for both patients and normal individuals.[20] This suggests that when impaired, vestibular input significantly impacts the head's angular position and more so when vision is secondarily impacted.

When combined, the three main sensory inputs (somatosensory, vestibular, and visual) create appropriate postural controls by initiating corrective postural muscular adjustments initiated by the central nervous system.[15,19] The vestibular system contributes to gaze stabilization, balance, and postural control by monitoring the body's orientation and its relation to gravity through the motion of head-in-space.[17,21,22] Two main types of organs are associated with the vestibular sensory organs of the inner ear: three semicircular canals and two otolith organs.[21] The semicircular canals sense angular acceleration in all three directions, and the otolith organs sense linear acceleration within all three directions.[21] To quantify vestibular sensory contribution, common tests include the Sensory Organization Test (SOT) which is used in patients with vestibular disorders, stroke, concussion, and Parkinson's.[15,23–25] The SOT test is commonly performed stationary in an upright position and uses perturbations to manipulate in some combination of the visual, vestibular, and somatosensory input.[15] In 2014, locomotion was added to these same conditions to assess the SOT during gait.[15] It was found that walking was affected by unimodal and multimodal sensory perturbations, and between visual and somatosensory input, visual was more dominant, especially in the ML sway.[15]

Visual Impact on Gait

As previously mentioned, the vestibular system contributes to the body's relationship to gravity and its orientation in space, as well as contributes to gaze stabilization and postural control.[17,21,22] During gait, visual input from the environment is used in the planning process of locomotion in anticipation of the environment in which gait is about to occur.[26,27] In a study done with virtual reality, it has been postulated that visual field dependency is significantly correlated with locomotive measures, and that individuals with a higher dependency on the visual field sensory feedback modulate their gait speed and trajectory.[28] Healthy individuals will use visual fixation to maintain gaze on a single point as a method of suppressing motion perception within the visual field to maintain postural control, while those suffering from visually-induced dizziness experience an increase in visual refixations as well as altered COP displacement and head kinematics.[29] It has been suggested that less postural sway is observed when there is less restriction on eye movement within the visual field while performing visual searching tasks, thereby suggesting freedom of eye movement correlates to better functional postural control.[30] While visual fixation is used to suppress motion perception, freedom of eye movement and visual scans of the visual field contribute to an increase in postural control and allows for anticipatory alterations in gait speed, trajectory, and stability.

Single and Dual-task Tandem Gait

While currently head position during tandem gait is not controlled for, modifications to the tandem gait test have included dual-tasks versus single-task tandem gait and have been increasing in practice during baseline and concussion testing protocol.[6,31,32] Outside of concussion testing protocol, dual-tasks have been used to examine attention distribution and the relationship to fall risk and postural imbalances.[8] Dual-tasks increase the demand for simultaneous cognitive and motor skills which is a more realistic representation of the athletes' skills and may suggest a longer-lasting impact on cognitive impairment post-concussion.[8] In a study by Howell et al in 2019, both single-task and dual-task tandem gait tests demonstrate sufficient reliability in a clinical setting.[8]

Purpose Statement

Head position, more predominantly vestibular sensory feedback, has an impact on postural sway and locomotion. However, concussion testing protocol using tandem gait and controlling the head position has not been investigated to date. The purpose of this study is to explore any measurable differences in ML COP sway, velocity, and time of completion between two different head positions of neutral and cervical flexion during single and dual-task tandem gait concussion testing protocol.

Hypothesis

We hypothesize there will be a significant difference in the ML COP excursion and velocity between the two different head positions in both the single and dual-task tandem gait testing parameters. Additionally, we expect to find an increase in time to completion with the head in cervical flexion for both dual and single-task trials.

METHODS

Participants

Using prior literature and pilot data, we expected to find a significant difference in the ML COP sway and velocity, and time to complete the trial during both head controlled positions at varying phases of the single and dual-task trials. With the data and information collected from the pilot study, a power analysis was conducted that indicated 14 participants were required to detect a statistically significant within subjects effect using a series of repeated measures ANOVA ($\alpha = 0.05$, $\beta = 0.80$).[14] Due to the ease of data collection and lack of a disease group, the goal was to collect data up to 28 participants. A total of 27 participants (Male=5, Female=22) were recruited for this study and 25 were included. The anthropomorphic data of the participants included 21.93 ± 1.41 years of age, 166.92 ± 13.53 cm in height, and 68.72 ± 19.41 kg in weight.

Inclusion criteria

Apparently healthy 18 to 25 year-old individuals were able to complete the tasks (n=25, 4 males and 21 females). Participants were given a short author modified medical history tool used for screening to determine eligibility and identify any exclusionary criteria, see appendix A.

Exclusion criteria

Individuals diagnosed with a concussion in the last 12 months, or a significant sensory deficit (ex: blindness, vestibular disorder, neuropathy, etc), were excluded from this study.[6,8] Additionally, individuals with a lower extremity deficit or injury which may affect gait were excluded.[6] One participant was excluded from the study due to having competed in a mixed martial art competition two weeks before testing, though no concussion had been diagnosed. Another participant was excluded from the study due to the length of time to complete the test, especially the turn, where the average of the three trials for each condition was more than double the second highest average. This may have been due to a limited understanding or misunderstanding of the test, or another unknown factor. Lastly, one participant's data indicated a single trial that equated to an increase in the ML velocity inconsistent with the other trials within the same condition and therefore was not included in the final statistical analysis.

Tandem Gait assessment

Each participant was asked to walk in alternating tandem heel-to-toe gait barefoot along a 3-meter piece of athletic tape affixed to the Teckscan Strideway – (Teckscan Inc. South Boston, MA).[8] An accepted trial was considered walking down the 3-meter tape, turning 180°, and repeating the same heel-to-toe gait back to the starting point without stepping off the tape or touching the researcher.[8] This is consistent with the SCAT3 and SCAT5 testing protocol, except this study did not have a pass/fail trail.[9,10] An unaccepted test was when the participant stepped off the platform, touched the researcher, broke contact with heel-to-toe placement, changed head position, or did not maintain eye contact with the visual target.[6] An unsuccessful trial was discarded and the participant was given one more attempt. If the second attempt was unsuccessful, the trial was not included.

To control the head position, the participant was instructed to fixate on a visual target affixed to a tripod one and a half meters from the ground and placed three meters from either end of the athletic tape in order to encourage the participant's head to remain neutral at approximately 90° to the floor.[18,20] To assess the head in flexion, the participant was asked to look at their feet while performing the task.

The single-task tandem gait trials were completed as previously mentioned and with the accompanying two head positions. The dual-task trials were completed as mentioned with the addition of a cognitive test performed during each trial that accompanies the two head positions. The cognitive test asked the participant to subtract by sevens from a randomly selected two digit number.[8]

Data Analysis

COP excursion and velocity were analyzed in the mediolateral plane and computed as the weighted average of center of pressure data recorded from the Teckscan Strideway for the first pass, turn, second pass.[18,33] The tertiary variable was the average time of three attempts to complete each of the phases. The first pass was defined as walking the length of the tape prior to the 180-degree turn, the second pass was defined as returning the length of tape after completing the 180-degree turn, and the turn is defined as the 180-degree turn necessary to successfully align oneself for the second pass. Additionally, the total time to complete the test was evaluated and consist of the summation of the three phases of the trials previously defined. A custom MatLab code (MatLab 2019b edition, The Mathworks Inc., Natik, MA) was used to process the raw data from the Teckscan Strideway and convert the data into the COP and Time variables for the three different phases of the tandem gait trial.

Statistical Analysis

A series of repeated measures ANOVA evaluated the within subject differences of the ML COP excursion of the first pass, second pass, and turn, the ML COP velocity of the first pass, second pass, and turn, and the variable Time for the first pass, second pass, turn, and total time to complete the test. Cohen’s D and eta squared were conducted to assess the effect size of the within subject differences.

RESULTS

First Pass

The results of the RM ANOVA for the single-task first pass noted a significantly higher amount of ML COP sway in the cervical neutral condition ($F_{(1,24)}$=8.71, p=0.007, Cohen's d=0.62) compared to the cervical flexion condition. The dual-task first pass indicated a significantly higher ML COP excursion with cervical neutral, (1.8±0.37cm) ($F_{(1,24)}$=12.73, p=.002, Cohen's d =0.73) when compared against cervical flexion (1.52±0.40cm), see Table 1.1. There was no significant difference in the ML COP velocity observed during the single-task trials ($F_{(1,24)}$=2.07, p=0.163, Cohen's d =0.17) during cervical flexion (8.69±3.18cm/s) and cervical neutral (9.24±3.44cm/s). The dual-task trials also noted no significant difference in the ML COP velocity ($F_{(1,24)}$=0.000, p=0.989, Cohen's d =0.002), see Table 1.2. There was no significant difference found in time to complete the first pass during the single-task trials ($F_{(1,24)}$=2.91, p=0.10, Cohen's d =0.14). However, a significant difference was noted in the time to complete the first pass of the dual-task trials between the conditions of cervical flexion (7.3±3.48s) and cervical neutral (6.45±3.06s) ($F_{(1,24)}$=11.571, p=0.002, Cohen's d =0.25), see Table 1.3.

In summary, the results of the first pass single-task and dual-task tandem gait trials, when the head position was fixed in cervical neutral, indicated participants swayed more in the ML plane. Secondarily, when the head position was fixed in cervical flexion during the dual-task trials it took longer to complete the first pass when compared to the head position of cervical neutral. However, this difference was negligible and was not consistent with the single-task trials where the time was nearly the same. Additionally, controlling for head position did not have an impact on the ML velocity during both single and dual-task trials.

Second Pass

The results of the RM ANOVA showed a significant difference in the ML COP excursion during the single-task trials for the cervical neutral condition (1.72±0.44cm) when compared against the cervical flexion condition (1.53±0.39cm), ($F_{(1,24)}$=5.255, p=0.031, Cohen's d =0.46). In addition to the single-task trials, there was a significant difference within the dual-task trials ($F_{(1,24)}$=19.632, p<0.001, Cohen's d =0.98) where more ML COP excursion was observed in the cervical neutral condition (2.00±0.50cm) compared against cervical flexion (1.58±0.34cm), see Table 1.1. There was no significant difference in the ML COP velocity found between cervical flexion and cervical neutral during the single-task trials ($F_{(1,24)}$=0.383, p=0.54, Cohen's d =0.07) or the dual-task trials ($F_{(1,24)}$=0.071, p=.792, Cohen's d =0.04), see Table 1.2. The results of the time to complete the second pass noted no significant difference in the single-task trials ($F_{(1,24)}$=1.218, p=0.281, Cohen's d =0.09). However, during the dual-task trials, a significant difference was found in the time to complete the second pass ($F_{(1,24)}$=4.917, p=0.036, Cohen's d =0.19) when the head is controlled for in cervical flexion (6.76±2.87s) versus cervical neutral (6.35±2.94s), see Table 1.3.

In summary, similar to the first pass, when the head position was fixed in cervical neutral during the second pass, there was more ML sway during both the single and dual-task trials. Consistent with the first pass, when the head was fixed in cervical flexion during the dual-task trials, it took longer to complete the second pass but was considered inconsequential. Similar to the first pass, the single-task trails of the second pass showed there was no difference in time between the two different head positions. Again, during the second pass, controlling for head position did not have an impact on the ML velocity during both single and dual-task trials.

Turn

The results of the RM ANOVA indicated no significant difference in the ML COP excursion when controlling for the head position during the single-task trials ($F_{(1,24)}$=3.30, p=0.08, Cohen's d =0.31). A significant difference in ML COP sway was found during the dual-task trials where more excursion was found with the head in cervical neutral (2.81±0.80cm) versus cervical flexion (2.29±0.58cm) ($F_{(1,24)}$=10.25, p=0.004, Cohen's d =0.74), see Table 1.1. Notably, A significant difference in ML COP velocity during the single-task trials was found during the cervical neutral head position (12.91±5.15cm/s) versus the head in cervical flexion (11.21±4.06cm/s) ($F_{(1,24)}$=.5.64, p=0.026, Cohen's d =0.37), but no significant difference was found during the dual-task trials ($F_{(1,24)}$=0.53, p=.48, Cohen's d =0.09), see Table 1.2. No significant difference in time to complete the turn was observed during the single-task trials ($F_{(1,24)}$=.08, p=.779, Cohen's d =.05) or the dual-task trails ($F_{(1,24)}$=.211, p=.650, Cohen's d =.04), see Table 1.3.

During the turn of the single-task trials, there was more ML velocity when the head position was fixed in cervical neutral. However, this was not consistent with the dual-task trails where there was no difference in the ML velocity during the turn phase of the trial. Unlike the first pass and second passes of the trials, there was no difference in the ML sway or time to complete the turn when the head position was controlled.

Total Trial times

No significant difference in total time to complete the test was noted between the head positions of cervical flexion condition (12.81s±4.94s) and cervical neutral condition (12.32±4.36s) during the single-task trials ($F_{(1,24)}$=.1.568, p=.223, Cohen's d =.11). However, the results of the dual-task trials had a significant difference in total time to complete the test when the head position was fixed in cervical flexion (16.5s±s6.92s) versus cervical neutral (15.13s±6.41s), ($F_{(1,24)}$=7.955, p=.009, Cohen's d =.21), see Table 1.3.

When the head position was controlled for during the single-task trials, there was no difference in total time to complete the test, suggesting that the head position did not have an impact on time to complete the test. Conversely, during the dual-task trials, a difference was found where the test took longer to complete when the head was fixed in cervical neutral. However, this difference in time during the dual-task trials was negligible.

DISCUSSION

The purpose of this study was to explore the difference in the ML COP excursion, velocity, and tandem gait trial times when the head position is controlled for. Confirming our hypothesis, a significant difference was found in the ML COP excursion for both single and dual-task tandem gait trials when the head position is fixed in cervical neutral versus cervical flexion. Our hypothesis confirmed a difference in the ML COP velocity, however, this was only indicated during the turn of the single-task trials and no significant difference during the other phases of the test for the single and dual-task trials. The original hypothesis stated there would be no difference in time, however, the dual-task trials had a significant difference in the time to complete the first pass, second pass, and total test time when the head was controlled for in cervical flexion. Whereas, the original hypothesis confirmed no difference in time to complete the test during the single-task trials.

The results of this study suggest more ML COP sway when the head position was controlled for in cervical neutral versus cervical flexion in both single-task and dual-task trials. The dual-task trials showed a significant difference during all three phases of the trial; first pass, second pass, and the turn, Figure 1.2. However, single-task trials had a significant difference in the first pass and second pass, but no significant difference in the ML COP sway during the turn, Figure 1.1. The average ML COP excursion for each pass found in this study is consistent with current literature for healthy subjects where the mean results of this study fall within the standard deviation.[14] When an increase in the ML COP sway is observed, suggestsing the individual is at an increased risk of falls due to the presence of postural instability.[13] It is often observed that an increase in postural instability is consistent with the diagnosis of a concussion.[1,6,7] While this study did not review or compare concussed individuals against healthy individuals, the presence of increased postural sway with healthy individuals when the head is fixed in cervical neutral suggests the possibility of an even greater magnitude of postural instability in concussed individuals should the head position be fixed in cervical neutral. During regular locomotion, somatosensory, as a reflex arc, provides proprioceptive afferent feedback while the vestibular system and visual system provides spatial awareness as reactive sensory feedback.[15,34] When the visual and vestibular systems are compromised, such as being fixed in cervical neutral and visual fixation, the somatosensory feedback is more relied upon to maintain postural control, especially during a novel task such as tandem gait.[12]

Specifically, within the dual-task trials, there was a significant difference in the ML COP sway during each of the three phases of the trials when the head is controlled. With dual-task trials, there is an addition of a cognitive test in conjunction with the tandem gait test. For this study, the cognitive test consisted of asking the participant to subtract from a random number by seven for the duration of the trial. Therefore, when the head is fixed, there is a restriction on the participants to freely look around during recollection of the cognitive test. Dual-task tandem gait increases the complexity of the test by placing an increased demand in attention task-switching.[35] For this reason, it is becoming more accepted in concussion assessment, especially for SRC because athletes are often needing to perform cognitive tasks with physical tasks. Typically during regular locomotion, eye movement patterns from the observer will scan the visual field in search of both observer-related and stimuli-related (such as an animal crossing the visual field) information to construct temporal information about the surrounding environment.[36] Explicit knowledge (expressed as written words, diagrams, and mathematical equations) and tacit knowledge (the knowledge to act in doing something) have strong correlations between eye movement patterns and the recollection of knowledge.[36] This concept of eye movement patterns connected with cognitive functioning is likely a contributing factor in the increased ML COP excursion observed in these dual-task trials. Therefore, when a cognitive task is added to a novel gait pattern, and the eye and head movements are restricted, it leads to the need to rely more on afferent sensory feedback and in return an increase in the ML COP sway.

The second variable observed in this study was ML COP velocity. While the turn of the single-task trial had an increase in velocity when the head was fixed in cervical neutral, the remaining passes of the single-task and the entirety of the dual-task assessment had no significant difference in the ML COP velocity between head positions, see Figure 2.1. When assessing COP velocity in the ML plane, the mean results of the trials are consistent with current literature alongside no significant difference in velocity when a significance of excursion is present.[14] In Murray et al., 2021 the mean ML COP velocity was established as being 10.35±2.63cm/s for the first pass in healthy controls, and 9.48±2.33cm/s during the second pass.[14] The mean trial results of this study fall within the norms, see Table 1.2. Therefore, it can be proposed that a fixed head position will not have a significant effect on the variable of ML COP velocity during this common SRC test. It is speculated that when a suspected SRC is being assessed, the decrease or no change in ML velocity may be due to the more conservative approach to gait when an individual is concussed.[14]

The third variable analyzed was the time to complete each phase of the single-task and dual-task trials. Acutely concussed individuals will take longer to complete the task when compared against healthy individuals.[14] Within this study, during dual-task tandem gait, a significant difference was observed when the head was fixed in cervical flexion

(16.5±6.92s) versus cervical neutral (15.13±6.41s). While the results of the RM ANOVA were significant during the dual-task trials, the effect size (Cohen's d=.21) of these results were small, suggesting a negligible difference in time to complete the test, see Figure 3.1. An explanation of this phenomenon may be in part due to the limited head and eye movement allowed when the head is fixed in cervical flexion explained by the concept of eye movement patterns connected with cognitive functioning.[36]

Limitations

In 2022 there were reportedly more than 522 thousand collegiate athletes with the National Collegiate Athletics Association (NCAA).[37] Of these 493 thousand athletes, 56.13% were male (293,105) and 43.87% were female (229,060).[37] The male-to-female demographics of this study (4 males and 21 females) does not accurately reflect the NCAA gender demographics. In future research, an emphasis on recruiting more male participants should be employed.

Participants that were included in this study were primarily recruited from the local university with jobs and classes that are closely related to the field of study of kinesiology. Thus, some individuals were familiar with the TG tasks and therefore may have been familiar with the protocols or the test assessment itself. Prior knowledge and or practice of the assessment may have been a compounding factor in the resulting data. Future research should not include participants who are familiar with the assessment.

While the participants were instructed to fixate on the visual targets at either end of the Strideway, the participants could have moments of freedom with their eyes and head which may be a compounding factor. The visual targets intended to fix the head and eye position; however, the head could still freely move. The application of a cervical collar to fix the head in cervical neutral may be explored in future studies as a method for fixing the head position. It has been reviewed that a cervical collar alone has no significant effect on the COP data during quiet stance, therefore maycompliment the study by fixing the head position.[38]

Future Research

Future research should include concussed and non-concussed individuals to explore any impact of controlling head position, especially in acutely concussed individuals. Common symptoms of concussions include visual disturbances and dizziness, therefore further research into fixing the head position and gaze stabilization within this injured population should be explored. Additionally, if the results of this study were to be applied to collegiate SCAT-5 testing, further research to include more male participants should be explored to more accurately reflect the NCAA demographics along with a larger sample size.

CONCLUSION

The results of this study suggest a significant difference in the ML COP excursion when the head position is controlled for during both single and dual-task tandem gait testing, with an increase in ML COP sway when the head position is fixed in cervical neutral. While no meaningful significant difference was observed in the ML COP velocity or time of completion, these results indicate further investigation to suggest a change in protocol to tandem gait testing. Thus, it could be suggested that the individual or subject be allowed to choose their head position and to keep that position consistent across testing procedures, with special attention to pre and post-testing conditions. The implications of this study could be applied to both clinical and research testing conditions for fidelity and reliability within the test. While further research is warranted, especially within concussed individuals, the initial findings of this study are promising.

TABLES and FIGURES

Table 1.1

Mean center of pressure of excursion in the mediolateral plane for the first pass (FP), turn, and second pass (SP), for both single and dual-task tandem gait trials with the controlled head position of cervical flexion and cervical neutral.

Condition	**Mean (SD) cm**	***P*-value**	**Cohen's d**
Cervical Flexion: FP – *Single-task**	1.49 (0.38)	0.007	0.62
Cervical Neutral: FP – *Single-task*	1.78 (0.54)		
Cervical Flexion: FP – *Dual-task**	1.52 (0.40)	0.002	0.73
Cervical Neutral: FP – *Dual-task*	1.80 (0.37)		
Cervical Flexion: SP – *Single-task**	1.53 (0.39)	0.031	0.46
Cervical Neutral: SP – *Single-task*	1.72 (0.44)		
Cervical Flexion: SP – *Dual-task**	1.58 (0.34)	<0.001	0.98
Cervical Neutral: SP – *Dual-task*	2.00 (0.50)		
Cervical Flexion: Turn – *Single-task*	2.25 (0.62)	0.082	0.31
Cervical Neutral: Turn – *Single-task*	2.45 (0.66)		
Cervical Flexion: Turn – *Dual-task**	2.29 (0.58)	0.004	.74
Cervical Neutral: Turn – *Dual-task*	2.81 (0.80)		

*Significant difference found within subjects, standard deviation: SD

Table 1.2

Mean center of pressure of velocity in the mediolateral plane for the first pass (FP), turn, and second pass (SP), for both single and dual-task tandem gait trials with the controlled head positions of cervical flexion and cervical neutral.

Condition	**Mean (SD) cm/s**	***P*-value**	**Cohen's d**
Cervical Flexion: FP – *Single-task*	8.69 (3.18)	0.163	0.17
Cervical Neutral: FP – *Single-task*	9.24 (3.44)		
Cervical Flexion: FP – *Dual-task*	8.27 (4.25)	0.989	0.002
Cervical Neutral: FP – *Dual-task*	8.26 (3.18)		
Cervical Flexion: SP – *Single-task*	8.53 (3.04)	0.542	0.07
Cervical Neutral: SP – *Single-task*	8.74 (3.04)		
Cervical Flexion: SP – *Dual-task*	8.28 (3.86)	0.792	0.04
Cervical Neutral: SP – *Dual-task*	8.15 (2.90)		
Cervical Flexion: Turn – *Single-task**	11.21 (4.06)	0.026	0.37
Cervical Neutral: Turn – *Single-task*	12.91 (5.15)		
Cervical Flexion: Turn – *Dual-task*	11.30 (4.46)	0.486	0.09
Cervical Neutral: Turn – *Dual-task*	10.94 (3.61)		

*Significant difference found within subjects, standard deviation: SD, seconds: s

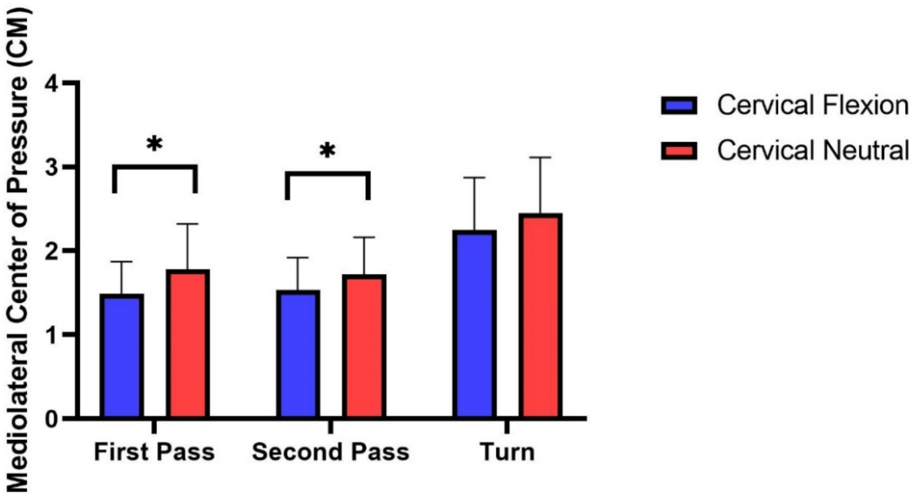
Table 1.3

Mean time of task completion for the first pass (FP), turn, second pass (SP), and total time to complete, for both single and dual-task tandem gait trials with the controlled head positions of cervical flexion and cervical neutral.

Condition	**Mean (SD) s**	***P*-value**	**Cohen's d**
Cervical Flexion: FP – *Single-task*	5.40 (2.14)	0.101	0.13
Cervical Neutral: FP – *Single-task*	5.12 (1.91)		
Cervical Flexion: FP – *Dual-task**	7.29 (3.48)	0.002	0.25
Cervical Neutral: FP – *Dual-task*	6.45 (3.06)		
Cervical Flexion: SP – *Single-task*	5.09 (2.17)	0.281	0.09
Cervical Neutral: SP – *Single-task*	4.90 (1.95)		
Cervical Flexion: SP – *Dual-task**	6.54 (2.67)	0.036	0.19
Cervical Neutral: SP – *Dual-task*	6.05 (2.58)		
Cervical Flexion: Turn – *Single-task*	2.32 (.71)	0.779	0.05
Cervical Neutral: Turn – *Single-task*	2.29 (.60)		
Cervical Flexion: Turn – *Dual-task*	2.67 (.92)	0.650	0.04
Cervical Neutral: Turn – *Dual-task*	2.63 (.89)		
Cervical Flexion: Total – *Single-task*	12.81 (4.94)	0.223	0.11
Cervical Neutral: Total – *Single-task*	12.32 (4.36)		
Cervical Flexion: Total – *Dual-task**	16.50 (6.92)	0.009	0.21
Cervical Neutral: Total – *Dual-task*	15.13 (6.41)		

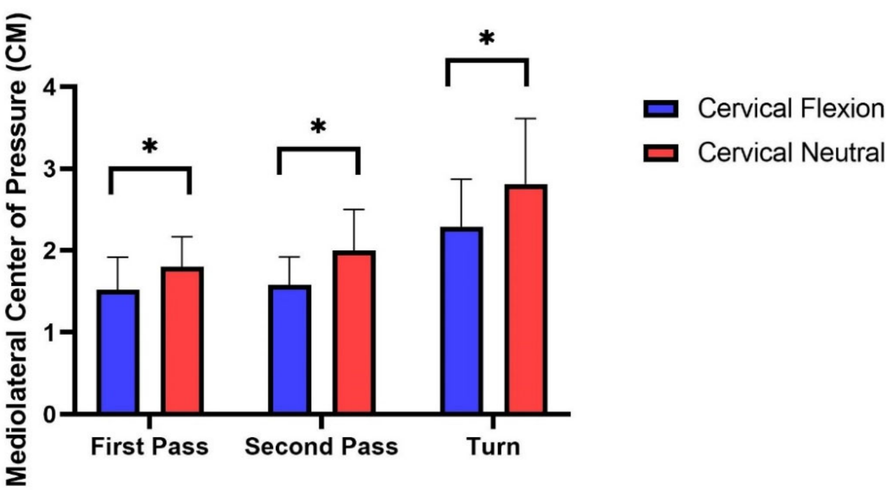
*Significant difference found within subjects, standard deviation: SD, seconds: s

Figure 1.1



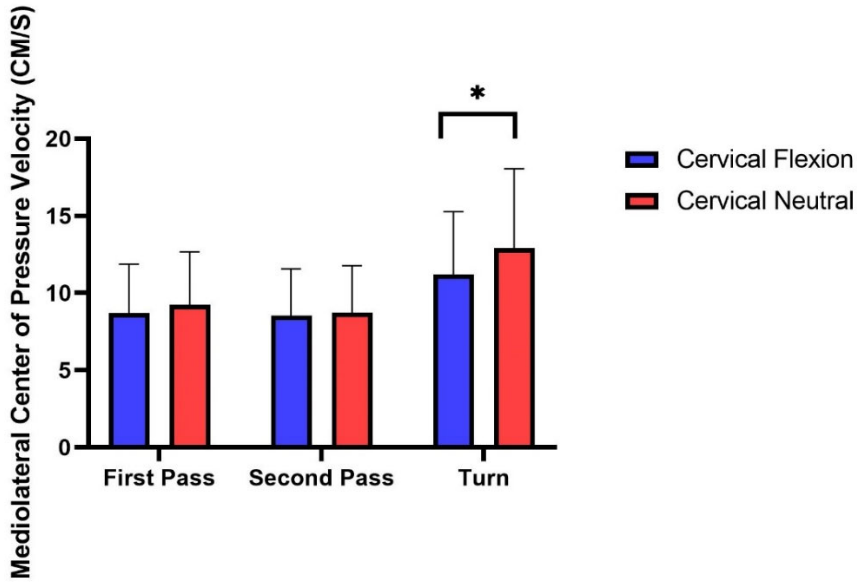
Single-task tandem gait differences in mediolateral center of pressure excursion between the controlled head position of cervical flexion and cervical neutral. *Indicates significant difference (p<.05)

Figure 1.2



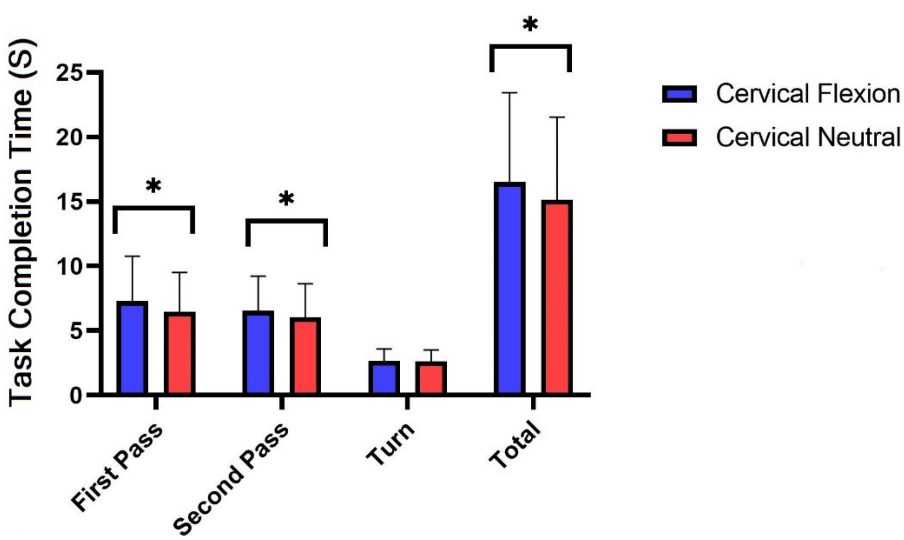
Dual-task tandem gait differences in mediolateral center of pressure excursion between the controlled head position of cervical flexion and cervical neutral. * Indicates significant difference (p<.05)

Figure 2.1



Single-task tandem gait differences in mediolateral center of pressure velocity between the controlled head position of cervical flexion and cervical neutral. * Indicates a significant difference (p<.05)

Figure 3.1



Dual-task tandem gait differences in time to complete the tandem gait trials between the controlled head position of cervical flexion and cervical neutral. * Indicates a significant difference (p<.05)

APPENDIX

Appendix A

UNIVERSITY OF NEVADA, RENO NEUROMECHANICS LAB MEDICAL HISTORY QUESTIONNAIRE

Please answer the following questions as honestly as possible. Your answers will remain confidential and will NOT be shared with your coaches or athletic training staff.

Subject ID ______________________ Date ___________________

Gender: Male ☐ Female ☐ Year in School: FR ☐ SO ☐ JR ☐ SR ☐ DOB: _______

Height: _______ Weight: _______

Please answer the following questions about your medical and injury history:

Concussion History:

1. Have you ever suffered a concussion? YES ☐ NO ☐

   If yes, how many? ____

   Please provide a short description of the incident(s), as well as when they occured:

   ____

   ____

2. Have you ever been "knocked out" playing sports? YES ☐ NO ☐

   If yes, please provide a short description of the incident(s): -

   ____

   ____

3. Have you ever "seen stars", been confused, or been disoriented playing sports? YES ☐ NO ☐

   If yes, how many times? _____________

   In the past year? __________________

4. Have you ever lost your memory after taking a hit playing sports? YES ☐ NO ☐

   If yes, please explain:

   ____

Musculoskeletal/Neurological History: (please note all injuries with significant time missed from practice/competition)

5. Have you ever sprained your ankle? YES ☐ NO ☐

   If yes, how many? LEFT: 0_____ RIGHT: ______ In the past year? _______ Time missed? ____________________

   Which is your "dominant" ankle? LEFT ☐ RIGHT ☐

6. Have you ever broken a bone in your foot or leg? YES ☐ NO ☐

   If yes, please explain: ____

   Does this injury still bother you? YES ☐ NO ☐

7. Have you ever hurt your knee? YES ☐ NO ☐

   If yes, did you ever tear a ligament/meniscus (please specify which)?: YES ☐ NO ☐

   If yes, did you have surgery? (date): ______________________________

8. Have you ever hurt your hip? YES ☐ NO ☐

   If yes, please explain: ____

9. Have you ever strained/tore lower extremity muscles? YES ☐ NO ☐

   If yes, please explain: ____

10. Have you ever injured your low back or had a nerve pathology? YES ☐ NO ☐

    If yes, please explain: ____

11. Do you have any known balance, metabolic, or neurological disorders? YES ☐ NO ☐

    If yes, please explain: ____

12. Have you had any other muscle, bone, or joint injury to your body? YES ☐ NO ☐

    If yes, please explain:

    ____

    ____

13. Have you ever been diagonosed with Attention Deficit Hyperactivity Disoder (ADHD)? YES ☐ NO ☐

14. To the best of your knowledge, are you nearsighted or farsighted or normal vision? Nearsighted ☐ Farsighted ☐ Normal ☐

15. Do you where corrective lenses for the vision impairment? YES ☐ NO ☐

Additional Notes:

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____

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