Establishing Normative Ranges for the Coefficient of Variability in the Marching-In-Place Test During Sensory Deprivation Using OptoGait System

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Abstract

There are a number of human senses that are utilized in maintaining a balanced system of gait. The human senses of sight and hearing are used along with sensory motor in order to maintain the symmetry of motion. Unpublished research done at Logan College of Chiropractic have collected normal variance ranges for the coefficient of variability in a young adult population. However, there exist some questions as to what parts the other senses of vision and hearing play on the coefficient of variability (CV) of symmetrical gait.

To our knowledge, there are no published studies that utilize a marching-in-place test as a means to objectively measure the cadence of the body with and without human sensory input. Previous work at this institution has demonstrated a normal standard CV of 4.5% exists in asymptomatic population. We believe these are un-quantified components of sensory proprioception. The goal of this research was to use the Marching-in-Place test on the OptoGait software with the OptoGait system to collect data and establish a normative range for the coefficient of variability with different sensory deprivations.

The mean, median and mode for CV data from Normal Marching, Eyes Closed Marching, Ears Covered Marching, and Eyes Closed/Ears Covered Marching were calculated. Evaluating only the descriptive data shows an interesting outcome of improved Mean CV with vision obstructed.

Introduction

Returning to play is the number one priority for athletes after sustaining an injury. It is in the best interest of the athlete if they return to play at a time when they are functioning at their optimal level of performance. Concussions have recently gained significant public health attention that has produced efforts on a national legislative platform to improve recognition and management (5). Echemendia and Cantu state that the effects of 'concussions can be transient or may lead to chronic, debilitating symptoms' (7). Lovell et al. state that mild concussion suffered by high school athletes showed a decline in memory processes that was significant compared to a non-injured control group (13). Returning to play after a concussion is one of the most difficult decisions that a physician has to make in the world of athletics. Putukian et al. states that management of concussions in the non-athlete will be managed more conservatively due to the lack of resources for treatment that the elite athlete would typically have available (21). Cantu and Register-Mihalik state that one of the major issues regarding concussions is the risk of chronic traumatic encephalopathy (CTE) (3). Establishing a normative value using the OptoGait system will help formulate a baseline that the physician or trainer can use to compare athletes in question. This study not only evaluates an individual's drift while marching in place with their eyes open, but it also evaluates an individual's drift with having vision obstructed, hearing obstructed, then the combination of vision and hearing being obstructed. The establishment of this type of normative value can be used as an objective form of examination to allow the physician or trainer to make a more accurate decision on return to play scenarios.

OptoGait is a system that is state of the art functional analysis tool that is aimed at 'injury prevention and rehabilitation (18). The OptoGait system is an optical measurement system that consists of two bars that constantly communicate to each other. One bar is a transmitting bar and the other is a receiving bar. If there is a disruption in the signal between the two bars and a recording made of the duration. Each one-meter bar contains 100 LEDs that allow for a very precise measurement up to 1/1000 of a second when there is a disruption of the signal. The software makes it possible to compare the data between multiple subjects and allows the user to obtain large amounts of data from small or large groups of subjects. The data that can be obtained from the one meter OptoGait bars are contact times, flight times, reaction time to sound/visual impulse, elevation of centre of gravity, specific power (W/Kg), frequency, and energy expended (J). (17)

Ideally, a physician should have their athletes mapped with the OptoGait system in the pre-season so there would be an individual baseline for the athlete to compare to if he or she sustains a concussion. Since this type of evaluation of an individual's drift while having various sensory stimuli obstructed using the OptoGait system is new to our knowledge, the use of a normal and healthy population was indicated to establish a normative value for return to play/work decision-making. We feel that the use of the OptoGait system along with the SCAT2 and ImPACT test, both recommended by the Zurich consensus statement, be the optimal tool in the diagnosis and management of concussions(8).

Materials & Methods

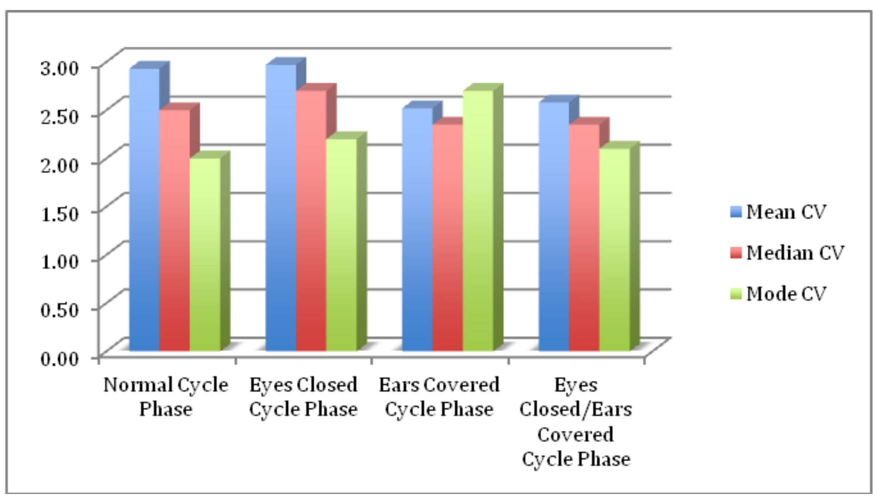
For this study, human test subjects were used over a period of two months. The individuals were pre-screened with questionnaires, and had to meet specific inclusion criteria, including: male or female ages 18-50 that were asymptomatic in the low back and lower extremities. Participants were excluded if they had current neck or low back pain with or without radicular symptoms extending below the elbow or knee at the time of participation. In addition, no subjects could have foot or ankle pain at the time of participation, a history of neurological disease, and/or severe lumbar spine trauma or surgery. Those known to have degenerative joint disease, a history of vertigo, injury to the lower extremity less than six months prior to participation, pregnant, diagnosed with diabetes, heart, kidney or thyroid or other chronic diseases, or were hearing impaired (hearing aids, cochlear implants, dead, or current ear tubes) were unable to participate. Individuals that were using or prescribed muscle relaxants or analgesics were also excluded from this study. Qualifying participants were then able to sign up for a 15-minute time slot for testing.

This study required the use of a 2-bar, one meter OptoGait gait biomechanics data collection system and accompanying software on a laptop computer. The first OptoGait data collection bar was placed horizontally on a flat floor surface. The second OptoGait data collection bar was then placed parallel to the first bar 6 feet apart. Each participant was then required to remove both his or her socks and shoes. Any individuals wearing long pants were further required to cuff their pant legs to a minimum of their visualized mid-tibia length. Once this was done, participants were then asked to enter between the OptoGait data collection bars, facing parallel to the bars, looking straight ahead with legs shoulder-width apart. Upon doing this, they were instructed that they would hear a ringing bell sound, which would indicate the beginning of the data collection. At the sound of the ringing bell, they would need to begin marching in place, starting with their right side/foot. They would then be required to continue marching in place until they heard a second ringing bell tone 15 seconds later, that would indicate the end of data collection. Following the second ringing bell, the participant was then instructed to step out of the data collection area. This part of the data collection was called 'Normal' Marching.

While the first piece of data collected from that participant was saved in computer, the participant stood and waited for further instructions. Once data was saved, the participant was then asked to return to the location between the bars, parallel, looking straight ahead with feet shoulder-width apart. They were then instructed to close their eyes. The participant then began marching in place, beginning with their right side/foot at the sound of the first ringing bell. At the sound of the second ringing bell, the participants were then instructed to stop, open their eyes and step out of the data collection area. Data for the participant was then saved. This phase of the data collection was called 'Eyes Closed' Marching.

The participant was then given his or her own pair of disposable, foam earplugs. The participant was then instructed to compress the earplugs and place them in their ears. Once the earplugs were fully expanded in the ears, the participant stepped into the data collection area, parallel, facing forward with legs shoulder width apart. At the sound of the ringing bell, the participant was given a hand signal in order to begin marching. At the end of the data collection, the same hand signal was given to communicate to the participant to stop marching and step out of the data collection area. Directions for this procedure, as well as the last data collection procedure were given to the participant prior to placing the earplugs in their ears. This phase of the data collection was called 'Ears Covered' Marching.

For the final data collection procedure, the participant entered the data collection area, looking straight ahead with feet shoulder width apart. The participant whom still had earplugs in place then closed their eyes. At the sound of the ringing bell, the participant was tapped on the shoulder to signal to begin walking with their right foot/side. At the end of the data collection, the participant was then tapped on the shoulder, signaling that they could open their eyes and remove their earplugs. This phase of the data collection was called 'Both (Eyes Closed/Ears Covered)' Marching.



During the collection of data, two individuals were present to act as 'spotters' in the event that a participant required assistance during data collection/testing. Following the completion of data collection, the collected data was placed in a Microsoft© Excel Spreadsheet. Any data that showed less than 12 total steps taken was removed prior to analysis. In addition, if data in any field was not collected by the system for a participant, the data collected for that individual was not used.

Although numerous fields of data are collected by the OptoGait system, the coefficient of variability (CV) was the data analyzed for this research. The CV is a percentage measurement of the amount of variability measured during a given phase of the marching/gait cycle for an individual. The mean, median and mode were then calculated for the CV's of the cycle phase, pace phase, flight phase and contact phase for each separate data collection phase ('Normal' Marching, Eyes Closed Marching, Ears Covered Marching and Both/Eyes Closed, Ears Covered Marching).

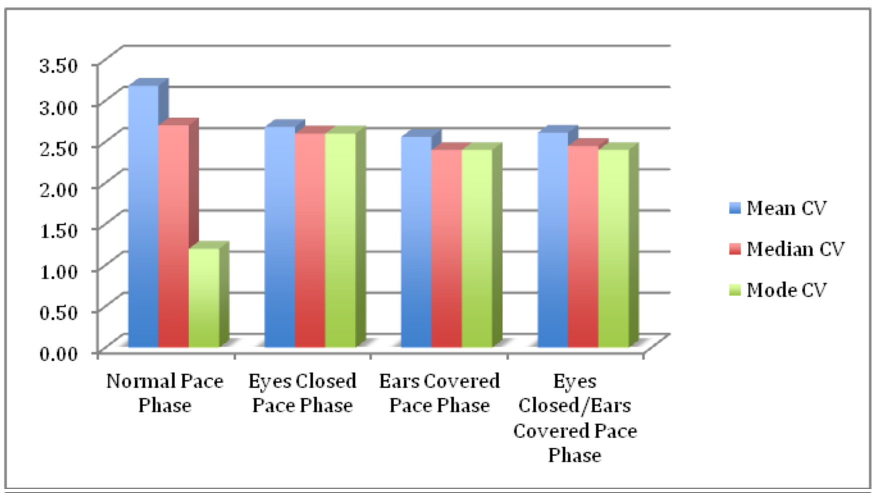
Results & Discussion

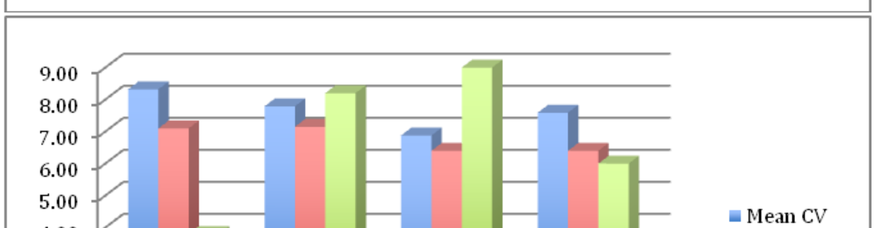
Cycle Phase

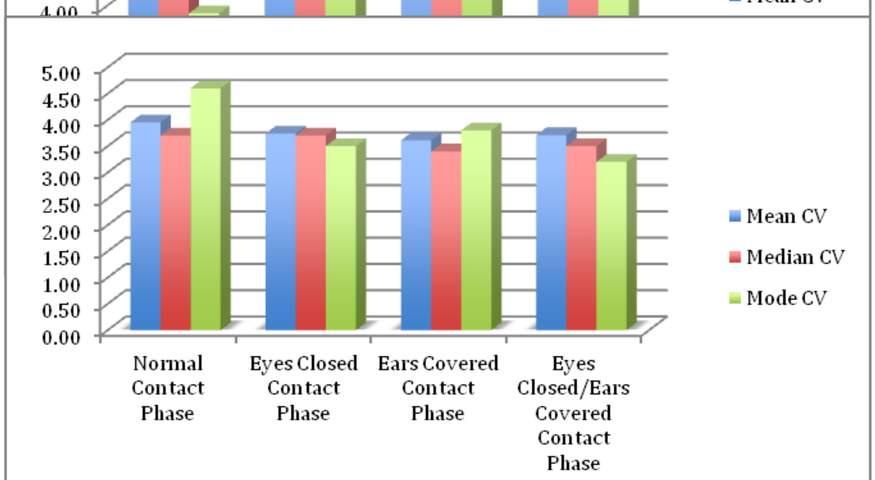
The Coefficient of Variable (CV) for the eyes closed test group showed only a rise of the Mean CV by 0.02 compared to the normal test group that had neither vision nor hearing obstructed. When the subjects marched with the obstructed vision only and the obstructed vision with obstructed auditory, the majority of the participants moved forward during their march. Studies have shown that with vision obstructed an individual would walk farther on solid ground than with vision not obstructed, and is associated with a blind-walking response that is increased (9,20). Durgin and Pelah state that the drifting forward is a result of 'recalibration of visuomotor control systems that takes place even in the absence of visual input' (6). This brings up an intriguing topic of the role of the brain when performing an activity without sensory input that it is used to having. Philbeck et al. states that the drifting during marching in place with vision obstructed and auditory obstruction may be 'at least partly an aftereffect of the states of motor adaptation elicited by normal, visually guided locomotion' (19). Nakamuara states that individuals who are visually impaired individuals have a significant shorter stride, slower walking speed, and more time in the stance phase of gate (16). Nakamuara also goes on to state that this is a mechanism used to allow visually impaired individuals to adapt to environmental conditions to maintain a more 'stable posture and to effect safe walking' (16). In both hearing obstructed only and vision obstructed with hearing obstructed the Mean CV improved from the normal group 0a.41 and 0.35 respectively. Our original assumption was that with the lack of sensory input the Mean CV would increase when in fact they decreased. Our assumption for this result

Figure 1 (above): *Mean, Median & Mode Values for the Cycle Phase*

Figure 2 (below): *Mean, Median & Mode Values for the Pace Phase*







Pace Phase

MacDougall and Moore stated that age, height, weight, body mass index, or gender did not show evidence of a correlation to the frequency of locomotion (14). Furthermore Murray et al. showed that there was no systematic relation between age and height to step frequency (15). Ivanenko et al. suggest that 'limb length and orientation might provide independent predictors of limb coordination' which in turn

Figure 3 (above): Mean, Median & Mode Values for the Flight Phase

Figure 4 (below): Mean, Median & Mode Values for the Contact Phase

may have an effect on the pace of an individual's march (11). Bloem et al. states that patients that have complete proprioceptive loss in the lower limb show that the surrounding musculature was delayed but not absent (2). This places an emphasis on the importance of proprioception and improving Mean CV with the absence of visual and auditory stimuli. The vision obstructed, auditory obstruction, and obstructed vision and auditory obstruction the Mean CV improved to 2.68, 2.56, and 2.61 respectively compared to the normal Mean CV of 3.18. Although P-values would have to be calculated to show any statistical significance, the results were surprising. Again the obstructed vision with auditory obstruction Mean, Median, and Mode CV improved compared to having only the vision obstructed. We believe a possible reason for the improved Pace Phase CV's is the bodies attempt to prevent movement by decreasing the amount of steps. This hypothesis is based on an individual's own compensation mechanism and to measure this is improbable.

Flight Phase

Obstructed vision (Mean CV =7.79), Auditory Obstruction (Mean CV= 6.88), and Obstructed vision with auditory obstruction (Mean CV= 7.59) all showed an improved Mean CV compared to the Mean CV of no vision or auditory obstruction (Mean CV= 8.32). Although we do not have P-Values calculated, Halleman and Aert's research showed a significant difference between full vision and no vision (10). Kitajima et al. found that the auditory-pupillary responses occurred in subjects that had bilateral deafness which lead to the conclusion that 'the auditory-pupillary response also relates to vestibular function' (12). Demer and Crane's research places an emphasis on the Vestibulo-ocular reflex stating that this reflex is what is used to stabilize gaze during natural movements (4). With this visual stimuli removed, an increase of vestibular activity is achieved which in turn is a possible answer to the improved CV with vision obstructed. We propose that with the auditory sensation removed the bodies' compensation mechanism for the loss of that sensory input is an increased vestibular function which may explain why the Mean CV for auditory obstruction was lower than all other Mean CV's.

Contact Phase

Other than the observation of the subject moving forward with vision obstructed, the foot and ankle musculature showed more visual activity when compared to the non-obstructed vision. To further evaluate the activity of the foot and ankle musculature, it would be interesting to have surface EMG probes on specific muscles to compare activation between vision obstructed and non-obstructed vision. Allum and Honegger states 'that information which is not available from one sensory system may be obtained by switching to another' (1), meaning with the loss of visual input the brain will rely on increased proprioception from the lower limbs. Along with that, the Mean CV of obstructed vision (3.74), auditory obstruction (3.61), and obstructed vision with auditory obstruction (3.71) were lower than the Mean CV of non-obstructed vision and non-obstructed auditory senses (3.95). Again, the lowest Mean CV was that of the auditory obstruction, which further supports the research of Kitajima, showing the vestibular function playing a role in the auditory-pupillary response (12).

Conclusion

Evaluating only the descriptive data shows an interesting outcome of improved Mean CV with vision obstructed. We believe that with the absence of visual input an increased proprioceptive component allowed the subjects to be more efficient while marching in place. We also believe that with the hearing obstructed the vestibular component of balance increases to a point that surpasses the proprioceptive input when vision is obstructed. In that case, we presume the vestibular component of auditory obstruction is more powerful than the proprioceptive compensation for visual obstruction resulting in an even lower Mean CV for having vision and hearing obstructed compared to just vision obstructed. The question of task familiarity arises due to the results of the Mean CV in the Cycle Phase, Pace Phase, Flight Phase, and Contact Phase which all showed an improved CV after the initial reading of non-obstructed vision with auditory sense not obstructed.

Furthermore ANOVA and Bonferroni-Post Hoc calculations would give more specific results to the data obtained from the OptoGait System. One problem we did experience with using the OptoGait system is when the subject would rotate, while having vision obstructed, to the left or right and their feet would overlap to where the system could not distinguish between the left or right foot so the system would stop recording. Ideally, an OptoGait system that accounts for rotation of the subject would be beneficial so that degree of rotation would be able to be recorded without missing any steps which would only add to the enormous amount of data that the OptoGait system collects.

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