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A pilot study of postural stability testing using controls: the modified BESS protocol integrated with an H-pattern visual screen and fixed gaze coupled with cervical range of motion

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Objective: *The purpose of this study was to investigate baseline postural stability of a normal healthy population using the modified balance error scoring system (M-BESS) integrated with H-pattern testing (HP) and cervical range of motion with fixed ocular gaze (CROM).*

Methods: *Postural error scores for twelve participants were scored during each twenty second trial of the M-BESS protocol stances (double-leg [DL], tandem [TL] and single-leg [SL]). Participants also completed the same M-BESS protocol with the inclusion of HP and CROM conditions for a total of nine trials.*

Results: *The total mean ± standard deviation and median of errors within each condition were not different*

Objectif : *Cette étude vise à étudier la stabilité posturale au niveau des pieds de sujets en santé en utilisant le système modifié de pointage des erreurs d'équilibre (M-BESS) intégré à l'examen des mouvements extra oculaires (modèle H) et l'amplitude de mouvement cervical (CROM) avec un regard oculaire fixe.*

Méthodologie : *Le pointage des erreurs de posture de douze participants a été marqué pendant chaque période d'examen de vingt secondes des positions du protocole M-BESS (deux-jambes [DL], en tandem [TL] et une seule jambe [SL]). Les participants ont également participé au même protocole M-BESS simultanément à l'examen des mouvements extra-oculaires (modèle H) et de la CROM pour un total de neuf essais.*

Résultats : *La moyenne totale ± l'écart type et la médiane des erreurs dans chaque état ne sont pas*

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(M-BESS 2.6 ± 2.1, 2.0; HP 1.3 ± 1.1, 2.0; CROM 2.0 ± 2.0, 2.0; p>0.05).

Conclusion: *Although a small sample size, our findings suggest that with normal, healthy, subjects challenging their visual input and cervical range of motion while balancing gives you a similar number of errors as the standard M-BESS protocol.*

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KEY WORDS: concussion testing, postural stability, H-pattern, BESS, mild traumatic brain injury.

différents (M-BESS 2,6 ± 2.1, 2.0, HP 1,3 ± 1,1, 2,0, CROM 2,0 ± 2,0, 2,0; p > 0,05).

Conclusion : *Bien que l'effectif de l'échantillon soit petit, nos résultats indiquent que l'examen des mouvements extra-oculaires (modèle H) et de l'amplitude de mouvement cervical (CROM) des sujets en bonne santé lorsqu'ils essaient de garder leur équilibre donne un nombre comparable d'erreurs à celui du protocole M-BESS standard.*

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MOTS CLÉS : tests de commotion cérébrale, stabilité posturale, mouvements extra-oculaires, BESS, lésion cérébrale traumatique légère, chiropratique

Introduction

The assessment of neuropsychological and postural stability for the management of concussion is gradually becoming more commonplace among sports medicine clinicians. Testing postural control provides an indirect means of identifying concussion related neuropsychological abnormality and serves as one of several recommended tools for determining readiness to resume activity.[1]

Recent research suggests that the use of a comprehensive approach, including postural instability assessment, may assist the health care provider in identifying signs of a concussion not easily detected during a routine clinical examination.[2] Within this comprehensive approach, baseline testing is an important component to preseason physical examinations. Baseline tests are used to establish an individual athlete's normal, pre-injury performance and to provide the most accurate and reliable benchmark against which post-injury assessments can be compared. This becomes especially important in the diagnosis and management of concussion, and subsequent return to play recommendations.

Maintaining balance requires the aid of visual, somatosensory (proprioceptive), and vestibular systems. Research shows that athletes often demonstrate decreased stability post-concussion.[1] The postural stability deficit can best be explained by a sensory interaction problem that prevents concussed athletes from accurately using and exchanging sensory information from the visual, vestibular, and somatosensory systems.[1] Large negative effects in postural sway are often identified at both immediate and follow-up assessment points, demonstrating the need for assessment of postural control as part of a concussion protocol. Difficulty in postural sway control may persist even after signs and symptoms of concussion recede.[3] Among these difficulties encountered are oculomotor and vision problems, many of which can impede daily activities. Blurred vision, light sensitivity and diplopia have been reported subsequent to concussive injuries, regardless of severity.[4] Problems with binocular vision, extraocular muscle function, and the accommodative system have also been found at relatively high frequencies.[5]

The M-BESS protocol has been established as an objective measure of balance. It has also been shown to have an increased number of errors in concussed patients compared to normal, healthy subjects.[2] Therefore, in this pilot study we investigated baseline postural stability of a normal healthy population using a modified balance error scoring system (M-BESS) protocol integrated with H-pattern testing and cerivcal range of motion with fixed occular gaze. We hypothesized that the inclusion of an H-pattern visual test or cervical range of motion with fixed gaze will not change the amount of errors scored during the M-BESS procedure in a normal healthy population. The findings of this pilot study may provide baseline data for further investigation that tests the efficacy of the new tests on a symptomatic population.

Methods

Ethical considerations

The current experimental protocol was approved by the Canadian Memorial Chiropractic College Research Ethics Board. Written informed consent was obtained from all volunteers before their participation in the study.

Participants

Our study population included 6 male and 6 female students from a post-secondary institution. Anyone who could walk freely without a limp or aid was included. Exclusion criteria included visual field deficits, blurred vision, light sensitivity, diplopia, current neck pain, history of ankle, knee or hip injury in the past 6 weeks, vertigo or dizziness, postural hypotension, and neuromusculoskeletal disorders that interfere with normal balance. Subjects with a concussion in the past 6 months or who had been diagnosed with post-concussion syndrome were also excluded from this study. A brief questionnaire, Neck Disability Index (NDI), Lower Extremity Functional Scale questionnaire and Oswestery low back disability index were all completed to assist in assessing exclusion criteria. Participants with an NDI >10% or Oswestery >10% were excluded.

Description of experimental maneuver

Our procedures were designed to parallel those used in the M-BESS protocol developed by researchers and clinicians at the University of North Carolina's Sports Medicine Research Laboratory.[6] The M-BESS is an integral component of the recently released Sport Concussion Assessment Tool – 3rd Edition (SCAT3).[2,6] The M-BESS is designed to be a portable, cost-effective, and objective method of assessing static postural stability utilized by clinicians in making return to play decisions following mild head injury.[6] We used the M-BESS as a framework for our study with alterations that focus on the effects of visual input and cervical range of motion on static postural stability. All test procedures were performed with the participants wearing shorts and shoes removed. This was done to standardize participant setup and to allow proper observation of any movements that could have caused failure during the testing protocol.

Three testing conditions were assessed in this study, which included: the standardized M-BESS protocol alone and combined with H-pattern (HP) and fixed gaze with cervical range of motion (CROM) in the three standard positions: double leg stance (DL), single leg stance (SL) and tandem stance (TL). Thus there were nine, twenty second trials quantified using a stopwatch and observers trained in the BESS protocol for scoring errors. We were only interested in the amount of errors that occurred in each 20 second trial in the various positions. The participants were randomly assigned an order in which they performed the nine trials. The nine trials were broken up by two minute periods of rest in order to prevent the effects of fatigue. The participants were also allowed to practice the various protocols for two minutes before testing began.

The three testing conditions were as follows:

1. Double leg stance:
   The participants placed feet together (touching) on a firm flat surface, hands on their hips and were asked to close their eyes. Participants were instructed to maintain hand contact on their hips while trying to maintain stability for 20 seconds.
2. Single leg stance:
   Foot dominance was determined by asking the participants "if you were to kick a ball, which foot would you use?" The foot that the patient indicated they would kick a ball with was identified as the dominant foot. The participants were then asked to stand on their non-dominant foot. The dominant leg was held in approximately 30 degrees of hip flexion and 45 degrees of knee flexion. A spotter assisted the participants into the appropriate position. Again, participants were instructed to maintain stability for 20 seconds with their hands on their hips. The participants were instructed that if they moved out of this position or stumbled, to open their eyes, return to the start position and continue balancing. We informed the participants that we counted the number of times they moved out of the set position.
3. Tandem Stance:
   For the final stance, participants were instructed to stand heel-to-toe with their

non-dominant foot in the back and their weight evenly distributed across both feet. As in the other two stances, participants were instructed to attempt to maintain stability for 20 seconds with their hands on their hips and that if they stumbled they were to open their eyes, get back into the set position and continue balancing.

H-pattern Test
For the H-pattern test, the spotter stood in front of the participants and instructed them how to get into one of the stances stated above. While holding this position, participants were asked to follow the instructor's finger with their eyes while keeping their head in a neutral position facing anteriorly. The instructors used their finger to trace an "H" pattern approximately 30 centimeters in front of them, making sure their finger moved far enough in a horizontal and vertical plane to ensure all visual fields were covered (ie. right-side up and down, left-side up and down). A metronome was used to standardize one H-pattern every 10 seconds for a total of two H-patterns per trial.

Fixed Gaze
For the fixed gaze tests, the spotter stood in front of the participants and instructed them how to get into one of the stances stated above. While holding this position, participants were asked to maintain eye contact with the instructor's finger placed approximately 30 centimeteres in front of them, while moving their head through full left rotation, right rotation, extension and flexion, respectively. After each movement, the patient returned to the neutral position. To ensure that each movement was completed twice in the 20-second trial, the patient paused in the neutral position for one second at both the beginning and end of each movement sequence.

Error Scoring
An error was credited to the participant when any of the following occurred;

- The hands moved off of the iliac crests
- Step, stumble or fall
- Abduction or flexion of the hip beyond 30 degrees
- Lifting of the forefoot or heel off the testing surface
- Loss of eye contact

The maximum total number of errors for any single condition was ten. If a participant commited multiple errors simultaneously, only one error was recorded. For example, if an individual stepped or stumbled, opens their eyes, and removed their hands from their hips simultaneously, they were credited with only one error. Subjects that were unable to maintain the testing procedure for a minimum of five seconds were assigned the highest possible score (ten) for that testing condition. Errors were not revealed after each trial to avoid any bias (ie. encouragement to beat their previous score). To avoid any injury, the testing was stopped if pain or dizziness with the participant was observed. For safety reasons, a spotter was present during all testing conditions.

Statistical analysis
According to Julious 2005[7], a sample size of 12 subjects in a pilot study is justified when reasons of feasibility, gains in the precision about the mean and variance, and regulatory considerations are taken into account. A one-way repeated-measures ANOVA was used to compare the independent effects of each condition (M-BESS, HP, and CROM) and stance (DL, TL, and SL) on postural errors. A one-way repeated measures ANOVA was also used after adding the total number of errors for each stance within each condition. For all analyses, when a significant main effect of condition was observed, post hoc comparisons were carried out with a paired-sample t-test corrected for multiple comparisons using the Tukey procedure. The level of significance was set to an α level of $P \leq 0.05$. All analyses were performed using the statistical software program Prism 6 for Mac OS X (GraphPad, La Jolla, CA.).

Results
The mean ± standard deviation physical characteristics of the participants were as follows: age: 25.6 ± 2 yr, height: 177.2 ± 8 cm, weight: 76.4 ± 12 kg.

The mean, median and standard deviation of errors during each protocol for each specific stance are presented in Table 1. There was a significant main effect of condition and stance on the number of errors scored during the testing procedures (p=0.01). The SL-M-BESS condition resulted in significantly more errors than the M-BESS-DL (p=0.03), and HP-DL (p=0.03) and HP-TL (p=0.03) con-

Table 1.
Mean, standard deviation and median error scores during the M-BESS protocol and M-BESS protocol combined with H-pattern (HP) and cervical range of motion with fixed gaze (CROM) for each stance.

Condition	Mean	Standard Deviation	Median
M-BESS-DL	0.0*	± 0.0	0
M-BESS-TL	0.4	± 0.7	0
M-BESS-SL	2.2	± 1.8	1.5
HP-DL	0.0*	± 0.0	0
HP-TL	0.3*	± 0.9	0
HP-SL	0.9	± 0.9	1
CROM-DL	0.3	± 0.7	0
CROM-TL	0.8	± 0.9	0.5
CROM-SL	0.9	± 1.1	0.5

DL – double leg; TL – tandem leg; SL – single leg. $P<0.05$, significantly different than M-BESS-SL (*).

ditions. No other conditions were significantly different ($p>0.05$).

The mean, median and standard deviation of the total number of errors (adding the total number of errors from each stance) for each protocol are presented in Table 2. No significant main effect of condition on the total number of errors between each condition was observed ($p>0.05$). This suggests that regardless of the stance, altering visual input and cervical motion does not change the total number of errors scored during the M-BESS procedure in a normal healthy population.

Discussion

Summary

To our knowledge, the present study is the first to examine the effects of the M-BESS protocol integrated with H-pattern testing and fixed gaze with cervical spine range of motion on the number of errors scored in a normal, healthy population. In the current study, calculated error scores using the M-BESS assessment protocol were not affected by varying visual input or cervical position. These results support our hypothesis that individuals who have not suffered a concussion or a mTBI, or are not currently suffering from neck, low back, or lower extremity injury, will score similarly when performing the M-BESS protocol with the addition of H-pattern testing or fixed gaze with cervical spine range of motion. However, we do not know how the results of the current study may differ with participants in the acute phase of a concussion. Given the effects mTBI or concussions can have on postural stability, ocular, vestibular, and somatosensory deficits[1,3,4,5,8,9], it is possible that including visual input and cervical spine range of motion in the M-BESS protocol

Table 2.
Mean, standard deviation and median of the total error scores for the M-BESS protocol, and M-BESS protocol combined with H-pattern (HP) and cervical range of motion with fixed gaze (CROM). Total error scores represent the summed totals of the three stances (single-leg, double-leg, and tandem-leg) for each condition.

Condition	Mean	Standard Deviation	Median
M-BESS	2.6	± 2.1	2.0
HP	1.3	± 1.1	2.0
CROM	2.0	± 2.0	2.0

may provide a more sensitive or specific testing tool for the diagnosis and management of concussions. Therefore, further investigation of the current study protocol on concussed subjects is warranted.

H-pattern

Dependent upon the severity and location of the injury, mTBI or concussion results in a spectrum of dysfunctions involving sensory, motor, perceptual, physical, behavioral, cognitive, linguistic and emotional aspects. Vision is a primary component of sensation and its deficits following mTBI will likely have an adverse effect on the patient's balance as well as many activities of daily living.[10] Visual dysfunctions following TBI or mTBI can be subsequently linked to the functioning and organization of the visual processing system.[11] Results of a study examining magnetoencephalographic (MEG) signals on visual-feature matching tasks in TBI patients versus healthy controls revealed an increase in gamma synchronization in the visual cortex of TBI patients, which authors propose "reflect the extra effort that the patients used to compensate for inefficient sensory processing due to disruption of cortical network by their injury".[11]

Approximately 90% of individuals with mTBI having vision-related symptoms examined in an optometric clinic setting were diagnosed with one or more oculomotor dysfunctions following their acute care phase and natural recovery period. Of the same sample population, 70% manifested non-strabismus types of oculomotor deficiencies involving version, vergence, and accommodation.[10] Vergence can be defined as disjunctive movement of the eyes in tracking objects varying in depth over the range of ones binocular visual field. The vergence system acts in synchrony and precision with the versional system to track objects laterally in one's visual space accurately and independently. The accommodative system is continuously activated to maintain target clarity. Five retrospective studies assessing the prevalence of oculomotor abnormalities in patients with mTBI, vergence dysfunctions range from 24-48%.[10] Identifying these abnormalities and rehabilitating them is essential in improving reading ability and overall quality of life.

The high prevalence of visual dysfunction following TBI or mTBI validates the necessity for the administration of a visual screen as part of both baseline and sideline concussion testing. The H-pattern test is an effective tool in assessing oculomotor functioning and the integrity of extraocular muscles, cranial nerves and the vergence system. The simplicity and convenience of the H-pattern test in combination with the M-BESS protocol allows for easy administration in both clinical and field settings, and could be an additional tool used to identify patients with an mTBI or concussion. The mean total numbers of errors during the M-BESS and H-pattern protocols in our study were 2.6 (with a median number of 2.0 and a standard deviation of ± 2.1) and 1.3 respectively (Table 2). Our M-BESS errors were similar to the normative reference values for the M-BESS for the corresponding age range of 20-29 years of age that showed a mean number of errors of 2.7 (with a median number of 2.0 and a standard deviation of ± 2.5).[12] These comparative results further validate our hypothesis that individuals who have not suffered a recent concussion or mTBI, or are not currently suffering from neck, low back, or extremity injury, will have no difficulty performing the M-BESS protocol with the addition of H pattern visual field testing.

Cervical Range of Motion

The vestibular system, in conjunction with visual and somatosensory input, acts to keep the eyes fixed on a stationary target in the presence of head and body movements. To accomplish this fixed gaze during cervical range of motion, the semicircular canals of the vestibular labyrinth sense angular acceleration of the head, converts this to velocity information and transmits it along the vestibulo-ocular reflex pathways to the ocular muscles. Concurrently, input of linear acceleration from the utricles and saccules of the inner ear is delivered via the vestibulospinal tract to the lower extremity and spinal muscles, which is necessary for maintaining balance.[1]

Accurate utilization and exchange of sensory information from the visual, vestibular and somatosensory systems occur during normal conditions. However, in subjects with possible vestibular or cervical spine dysfunction, such as after a mTBI, these processes can be disrupted or provide conflicting information.[1] Following a mTBI, two potential mechanisms for vestibular dysfunction exist: (i) the peripheral receptors themselves may be damaged and provide inaccurate senses of motion, or (ii) the brain centers responsible for ventral integration of vestibular, visual and somatosensory information may be impaired. Another mechanism of injury regarding neural deficits causing postural instability following an mTBI is also debated. It has been proposed that minor axonal dysfunction at the level of the brainstem or cerebellum may be a potential cause.[13] Taking this into consideration, assessing potential cranial nerve dysfunction as an underlying cause of instability using cervical range of motion with a fixed gaze may be warranted in individuals with an acute mTBI or concussion.

In the current study, we incorporated cervical range of motion with a fixed gaze into the M-BESS protocol in a healthy population. The number of errors scored was similar to the M-BESS protocol[12] and therefore more research is needed to determine how patients with a recent concussion score compared to healthy controls.

Limitations

Repeat administration of the postural stability tests warrants concern for possible short-term practice or learning effects that can influence test score results. For example, Valovich et al reported that high school athletes scored significantly fewer errors on repeated administration of BESS testing 7 days after baseline.[14] To compensate for any short-term improvements unrelated to the difficulty of each individual test, we randomized the ordering of the trials and allowed a 2-minute period where the participant could practice the different stances and protocols.

In addition to a learning effect, we must also consider the possibility of fatigue when performing numerous postural stability tests in succession. Wilkins et al found that performance in a controlled clinical laboratory environment resulted in decreased total BESS scores after a 20-minute fatigue protocol.[15] Susco et al also found that BESS scores were adversely affected by fatigue immediately after exertion.[16] To account for fatigue, we ensured that our subjects did not participate in any exercise prior to the administration of the testing protocols. We also allowed a 2 min break between each stability test.

Finally, another limitation to this study is the fact that the participants were a small, convenient sample of healthy, athletic students. This may limit our findings to a young and athletic population, as baseline errors may be higher in an older population who is not athletic.

Perspective and Significance

Since concussions are so prevalent, the development of valid and reliable testing protocols would have large clinical benefits. Various concussion testing protocols have been developed to help assist in the diagnose of a concussion, and baseline testing is vital for reasonable pre and post concussion comparability. Once a concussion has been diagnosed, these concussion testing protocols have great value in determining severity, patient progress, and resolution. Impact from an initial mTBI does not result in permanent structural damage, but rather causes temporary functional impairment. However, a person who has sustained a concussion is more succeptible to a subsequent concussion, and risk of permanent damage. Thus, valid and reliable objective measures of concussion are necessary to ensure the patient has recovered completely before normal activities of daily living and sport are resumed.

Patients who have sustained a concussion display a variety of symptoms ranging from cognitive, emotional, somatic, balance and sleep disturbancees. While symptoms vary from patient to patient, one of the most common is balance disturbance.[17,18] Therefore testing balance in a patient who is suspected of having a concussion may be critical to its diagnosis. Often balance disturbances persist longer than emotional or cognitive impairements so this may also be a better indicator of the recovery process. Studies done to date pertaining to concussions and the effect that concussions have on balance have primarily assessed balance via the BESS or M-BESS protcol.[19] While the BESS protocol is designed to measure static postural stability, we know that there are multiple systems that influence static posture, including the visual system and proprioceptive feedback from the cervical spine. The existing literature is very limited in the assessment of these aspects of postural stability and their relation to concussion diagnosis and management. Consequently, our study is the first to incorporate these influences on static posture into the M-BESS sideline protocol in a normal healthy population.

The intention is that now this information can be used as a base-line comparison to test the effect that concussions have on these aspects of postural stability. It is our goal to take this protocol and evalute its effect on participants in the acute phase of a concussion. We would also like to include our protocol in the baseline concussion testing of a few competitive sports teams (i.e. men/womens rugby). This will help us generate more baseline data to confirm the findings of the current study and provide us with a means to recruit participants in the acute phase of a concussion who already have baseline data that we can use for a strong statistical analysis.

In conclusion, based on the design of our study and the results obtained during testing, the M-BESS protocol with fixed gaze and cervical spine range of motion, and H-pattern testing can easily be incoporated into side-line concussion testing. Future studies are needed to determine if the addition of visual input or cervical motion to the M-BESS protocol results in more errors in patients who have suffered a mTBI or concussion. Similar to the M-BESS protocol, these tests are easy to administer, require minimal equipment and technical skill, and may be a tool for health care professionals to more effectively diagnose and manage patients with concussions.

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