TRAINING POSTURAL CONTROL WITH EYES-CLOSED VS EYES-OPEN AND EFFECTS ON POSTURAL CONTROL IMPROVEMENT

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ABSTRACT

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Introduction: Ankle sprains are one of the more common injuries in an athletic population. Postural control training can be used in prevention and rehabilitation for ankle sprains. When used preventively postural control training can decrease the risk of sustaining an ankle sprain by 38% (McGuine & Keene, 2006). There are a variety of postural control training programs all emphasizing different aspects of postural control, such as eyes closed, or eyes open situations. Training protocols with either eyes closed or eyes open have been shown to improve both static and dynamic postural control (Zech et al., 2010). The purpose of this study is to determine if training postural control with eyes-closed has the same effect on postural control improvement as training postural control with eyes-open.

Methods: Out of season collegiate athletes will undergo a 3 day per week postural control training program for 6 weeks. The participants were be split into two groups, one group did the entire training program with their eyes-closed and the other had their eyes-open. Static and dynamic postural control were measured using the mCTSIB and Limits of Stability tests, on the Biodex Balance System before and after the training program.

Results: Neither the eyes-closed or eyes open group significantly improved static or dynamic postural control ($p > .05$) after a 6-week postural control training program. There was no significant difference between individuals that trained with their eyes-closed or eyes-open ($p > .05$).

Conclusion: The results of our study indicate that neither eyes open nor eyes closed postural control training improves postural control over a 9 session/ 6-week training period.

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INTRODUCTION

Ankle sprains are one of the more common injuries in the athletic population. Among soccer athletes ankle sprains make up 17% of all injuries (Ekstrand. J, 1990). Willems et al (2005) investigated the possible risk factors for ankle sprains, and found that reduced postural control was associated with ankle sprains (Willems et al., 2005). Postural control refers to balance, typically while not moving, static balance, but may also refer to balance while one or more body parts are moving, dynamic balance. In this same study, poor dynamic balance measured using a limits of stability test was also associated with a higher risk of sprains (Willems et al., 2005). Testing postural control ability could be effective in pre-participating exams to identify individuals at higher risk of sustaining an ankle injury. In addition to reducing the risk of injury, postural control training could also be used to rehabilitate individuals who have sustained an ankle injury.

Postural control testing can be used in pre-participating exams for many sports. When screened in pre-participating exams, individuals with poor postural control were more likely to sustain an ankle injury in Australian football (Hrysomallis et al., 2007), basketball (McGuine et al., 2000), and soccer (Tropp et al., 1984). Of the athletes with poor postural control 42% sustained an ankle injury, compared to 11% of athletes with good postural control (Tropp et al., 1984). Identifying those with poor postural control can improve the care, by recommending a postural control training program. An effective postural control training program could reduce the risk of sustaining an injury. In addition to reducing the risk of injury, postural control training could also be used to rehabilitate individuals who have sustained an ankle injury.

Postural control training can be an effective intervention for both prevention and rehabilitation of ankle injuries. Healthy individuals that underwent a season long postural control training program that incorporated static and dynamic exercises, eyes open and closed situations, and exercises on different support surfaces were 38% less likely to sustain an ankle injury (McGuine & Keene, 2006). Along with reducing the risk of ankle injury, postural control training can also be used for rehabilitation. Individuals that underwent a season long postural control training program after a previous ankle injury were less likely to reinjure their ankle (McGuine & Keene, 2006). Individuals with chronic ankle instability saw improvement in both static and dynamic postural control and self-reported better function after completing a postural control training program (Mckeon et al., 2008), showing the effectiveness of postural control training in both prevention and rehabilitation of ankle injuries.

Postural control occurs under two primary conditions, static or dynamic. Static postural control is the control of the body's center of mass (CoM) over a stable base of support (Hinman, 2000). Static postural control can be accurately measured using force/CoM sensing platforms such as the Biodex Balance System (Biodex Medical Systems, Shirley, NY) to calculate stability index. Stability index measured from the participants' center of pressure on the force platform and their body height represents the average sway of a person's center of mass in all directions. An individual that has a stability index score close to 0 is considered to have good static postural control, and as the stability index score increases static postural control ability decreases (Hinman, 2000). A commonly used static postural control test used is the modified Clinical Test of Sensor Integration in Balance (mCTSIB). The mCTSIB has the participant maintain static postural control during four different conditions that alter proprioception and or visual sensory information (i.e. eyes open and eyes closed on a firm surface, eyes open and eyes closed on a foam surface) (Pagnacco et al., 2008). From these trails, a stability index for each condition and an overall stability index for that individual is calculated.

Dynamic postural control is the control of the body's center of mass (CoM) over a moving base of support due to one or more body parts moving (Hinman, 2000). Dynamic postural control can be measured using the limits of stability (LOS) test. LOS is defined as the maximum angle a body can achieve from vertical without losing balance. Using a force platform such the Biodex Balance System an individual uses visual feedback with whole body learning to move a cursor representing their CoM location in different directions between various points on a screen in front of the participant. The participant is told to complete each task as quickly as possible and move the CoM cursor as straight as possible between the two distant points. (Biodex Medical Systems, Shirley, NY). The Biodex algorithm then calculates a limits of stability score, or a percentage of the total distance traveled in all directions. Individuals with a low LOS score are deemed to have poor dynamic postural control, while individuals with a high LOS score are deemed to have good dynamic postural control.

Both static and dynamic postural control use three different sensory systems to correct the center of mass over the base of support. The three systems are vestibular, somatosensory, and vision. This can be represented in a model developed by Van Asten, Gielen, & Denier van der Gon (1988). The sensory systems provide information about the environment, a stimulus. That stimulus identified through each sensory system is then used to create a motor output that keeps the center of mass within the base of support. This process is happening continuously as the situation changes, creating a continuous feedback loop (van Asten et al., 1988). This would be advantageous for an ever-changing environment as the information gathered from each sensory system would change constantly, and a different motor output will be needed to keep the center of mass within the base of support. Each sensory system provides different and important information about how an individual's center of mass is interacting with their environment.

The vestibular sensory system located in the inner ear helps stabilize the head over the body's center of mass. Vestibular information used for postural control includes linear and angular acceleration of the head (Mergner & Rosemeier, 1998). This system is considered the primary sensor for gravity during postural control (Peterka, 2002). Disturbances to posture at the head, such as a push to the head or shoulders, primarily uses vestibular information to correct posture (Horak et al., 1994). Vestibular information is not as reliable when postural disturbances come from the base of support, such as slipping or tripping. In those situations, the postural control system relies more on the visual and somatosensory, proprioception, systems to gather appropriate information to correct posture.

The somatosensory system consists of proprioceptive receptors throughout the whole body. Receptors located in muscles and joints signal position and movement, while the receptors on the sole of the foot signal changes in pressure and sheer force of the support surface (Inglis et al., 1994). The stimulus produced by these receptors are integrated by the brain to produce a more accurate signal to the postural control system (Kavounoudias et al., 1999). Somatosensory information helps us identify where the body is in relation to the environment, as well as the quality of the support surface and ground reaction force (Mergner & Rosemeier, 1998). When an individual slips or trips somatosensory information is primarily used to maintain the center of mass within a base of support (Horak et al., 1994). If somatosensory information is unreliable, than vestibular information input will increase to compensate for loss of information (Horak et al., 1994). However, when healthy subjects and subjects with impaired vestibular loss are given the same accurate somatosensory information, there was no difference in postural sway correction (Peterka, 2002). These results suggest that individuals with vestibular loss do not entirely rely on somatosensory information for postural control. In fact this same study found that individuals with vestibular loss rely more on visual information to correct postural displacements (Peterka, 2002). When somatosensory information is unreliable such as standing on a foam surface, visual and vestibular information will compensate for the lack of information and make the correct postural adjustments.

The visual sensory system in postural control, senses motion of the environment and/or the motion of the body in the environment (Bardy et al., 1999). The motion is detected by the retina and processed as self-motion or movement in the surrounding environment (Redfern et al., 2001). However, when self-motion and environmental motion occur at the same time, it can become difficult to process the conflicting information and postural control instability can occur. In these situations the somatosensory system may compensate for the unreliable visual information and improve postural control stability (Redfern et al., 2001). When multiple sensory systems are altered, such as the visual environment and support surface, the motor control of the body will often correct itself in the direction of the visual stimulus (Redfern et al., 2001). It has been hypothesized that this reliance on visual information as compared to somatosensory of vestibular information could be due to vision being able to detect environmental motion as compared to somatosensory and vestibular information which only detects self-motion (Paulus et al., 1987). With corrections to postural control favoring visual information, it could be beneficial to alter vision when training postural control. While postural control training typically incorporates all three sensory information with the manipulation of one or more sensory systems, it may be more beneficial to use postural control training with a focus on altering visual information considering how the brain may favor visual information for postural control.

Balance training is an effective method of improving postural control. A systematic review published in the *Journal of Athletic Training* took the results of balance training studies, suggesting that not only can balance training improve postural control in healthy adults but balance training can be effective in rehabilitation of an injury. The improvement in postural control is thought to be due to neurological adaptations rather than muscular strength. This same study found that improvement in neuromuscular control was the same among healthy and non-healthy individuals, with no difference in amount of improvement in either group. The same review found that the training program should be at least six weeks to elicit notable training adaptations (Zech et al., 2010). This review only looks at improvements between different populations and duration of program. It neglected to compare the different training programs.

Postural control training consists of many different strategies, some alter one, two, or none of the sensory systems associated with postural control. One study looked at postural control training among only individuals with postural control disorders. This study focused on an upper body motion-oriented training program; motion-oriented meaning exercises emphasized head movement. They found that this kind of training program was effective for those with postural control disorders. This study did not however have a control, or non-training group, to compare their results (Shepard et al., 1993). Hoffman & Payne (1995) compared the effects of a postural control training program with altered somatosensory information, where half the participants underwent a balance training program while on an unstable surface. They found that postural control did improve when compared to a non-training group (Hoffman & Payne, 1995). While several studies have shown that balance training programs will improve postural control when compared to non-training, few studies have compared differences in postural control between training methods.

Comparing the effects of different training programs would greatly enhance the clinical use of balance training among physical therapist, occupational therapists, and athletic trainers. Cox, Lephart, & Irrgang (1993) investigated two groups doing the same training program, only differing in the surface, hard or foam, they stood on while performing the exercises. At the end of the program both groups showed improvement in postural control but there was no significant difference in the amount of improvement (Cox et al., 1993). While this study only altered somatosensory information during the training program, altering another sensory system or a different system could produce greater improvements in postural control. Another study used virtual reality to alter two sensory systems, somatosensory and visual, at the same time (Yen et al., 2011). Individuals were asked to stand on a force plate that requires them to move their center of mass to navigate a virtual reality world. This virtual reality group was compared to another training group that underwent a more standard postural control training program. That standard training program had the participants perform a static and dynamic balance exercise. Static exercises were single leg stance on a firm surface, with the ability to progress in difficulty, such as standing on a firm surface or eyes closed. The dynamic exercises include catching a ball while moving and going into a held double leg mini squat position. They found that while both groups improved postural control, there was no difference in the amount of improvement between the two different training programs (Yen et al., 2011). While both studies incorporated altered visual information in their training programs, the effects of balance training using only altered visual information on both static and dynamic postural control has yet to be investigated.

Vision is an important part of postural control especially during dynamic sports. A study comparing static postural control among runners, jumpers, and rugby players found that when vision is removed and postural control worsened in all athletes (Hammami et al., 2014). However, their results showed that athletes participating in a sport that require more complicated movements had better eyes-closed static postural control. These results lead to the recommendation of training postural control with both eyes-open and eyes-closed (Hammami et al., 2014). While this study recommends balance training with both eyes-open and eyes-closed conditions, it did not investigate the effects of using training programs that incorporate these two conditions. To the best of our knowledge, no study has investigated differences between eyes-open and eyes-closed balance training programs on static and dynamic postural control.

In summary, postural control utilizes a continuous feedback system that takes information from vestibular, somatosensory, and visual systems to produce a motor output that keeps an individual's center of mass within their base of support. Each sensory system provides different and important information for postural control. Depending on the situation different sensory systems will be the primary contributor to postural control. Good postural control has been shown to reduce the risk of sustaining an ankle injury (Hrysomallis et al., 2007; McGuine et al., 2000; Tropp et al., 1984). Postural control training is an effective way of improving postural control (Zech et al., 2010). Postural control training programs differ from one another, based on the task and the sensory information that is altered. Whether one or multiple sensory systems are altered, training programs have been shown to improve postural control. It is unclear if a balance training program that uses, an altered vision condition, such as eyes-closed, will effect static and dynamic postural control the same as a balance training program that does not alter visual information. The purpose of this study is to determine if balance training with eyes-closed effects postural control in the same way as training with eyes-open. The results of this study may be useful to physical therapists, occupational therapists, and athletic trainers as they design postural control training protocols in their clinical practices.

METHODS

Participants

21 collegiate track & field athletes (M:14 F:7; age: 18-22 years) were recruited to participate in this study during the off-season, as a supplementation to regular team training and practices. All participants were free of neurological or vision disorder and any current orthopedic leg injury or injury within the past six months prior to the beginning of the study or during the duration of the study. All participants were informed of the risks involved with the study and gave written informed consent before participation in accordance with the Humboldt State University Institutional Review Board.

Prior to the pre-test, participants were provided with a verbal and written description of the study explaining the time requirements, confidentiality, procedures, risks, and benefits of the study. Participants were then asked to complete a questionnaire about demographics and pertinent medical information to ensure they meet the inclusion criteria.

Experimental Design

Participants performed a pre- and post-intervention postural control tests. In-between the pre and post-tests they participated in a postural control training program 2-days per week for 6-weeks. The experimental group completed every postural control exercise with their eyes-closed (EC), while the control group completed the same exercises with their eyes-open (EO). The pre- and post-intervention postural control tests were performed on a Biodex Balance System included the modified Clinical Test of Sensor Integration in Balance (mCTSIB) to measure static postural control as a stability index, and the Limits of Stability (LOS) test to measure the participants dynamic postural control.

Balance Testing

Participants completed both the mCTSIB and LOS on the Biodex Balance System. Participants within each group performed the pre- and post-test in a counter balanced randomized order, half of the participants in each group performed the mCTSIB test or the LOS test first. During the mCTSIB test participants maintained their center of gravity (CoG) over their base of support (BoS) in four different conditions. The first and second condition were performed while standing on a firm surface with eyes open and with eyes closed, respectively. The third and fourth condition were performed while standing on a foam surface with eyes open and with eyes closed, respectively. For the mCTSIB test, the stability index was calculated for each condition and a composite (overall) stability index.

The LOS test has the participant use their postural control move a cursor representing their CoM location from a center target to a peripheral blinking target and back to center as quickly as possible while also keeping the path as straight as possible. The participants completed the same process for nine different targets in a random order. LOS measures overall time to complete the test as well as LOS scores for each direction and a composite LSO score. The composite and the directional LOS scores are calculated by dividing a straight line between each target by the actual path taken by the participant. This number was then multiplied by 100 to be represented as a percentage, or directional score. This percentage represents the participants outermost range they can lean without taking a biomechanical correction, such as moving a foot to prevent a fall.

Training Program

The balance training consisted of 12 total trainings sessions, designed to be 2-days a week for 6 weeks. To promote adherence, we allowed participants to complete the training exercises before or after their team organized practice. The participants were organized by postural control ability then split semi-randomly into two groups such that each group had a similar number of participants with equivalent postural control. The experimental group completed the balance training protocol with their eyes closed and the control group completed the balance training protocol with their eyes open.

For both the eyes open and eyes closed balance training, the first balance exercise was a single-leg stance on a foam Airex pad for 3 sets of 30 seconds. During this exercise the participants stood on their dominant leg, while the other leg is lifted off the ground with hip flexion of ~30 degrees and knee flexion of ~90 degrees. Dominant leg was deemed the preferred foot for kicking by the participant.

Participants also completed a double-limb Bosu ball balance for 3 sets of 30 seconds. For this exercise the participant went on the flat side of a Bosu ball, with feet shoulder width apart and go down into a mini squat and maintain that position for 30 seconds.

Each participant than completed the single-leg Y-pattern toe touch exercise for 3 sets of 8 reps. For this exercise participants-maintained balance on their dominant leg while reaching with the toes of the contralateral leg out as far as they could in the anteromedial, anterolateral, and posterior directions. The participants completed each direction eight times.

The last exercise of the training protocol was the single-leg stance T-birds exercise for 3 sets of 8 reps. For the T-Birds exercise, the participants stood on their dominate leg and flexed their hip reaching out with the same side arm as far down as they could safely or until they touched the ground. The participants had their arm flexed at 90-degrees throughout the whole motion.

These exercises were selected so both the control (EO) and experimental (EC) groups could perform them safely, while also training both dynamic and static postural control. During all exercises the participants had a member of the research staff serving as a spotter to ensure participant safety. Once the participant finished all the exercises, they signed out as a record of adherence to the training program before leaving the training area.

Data Analysis

To test the null hypothesis that static and dynamic postural control will not differ between groups, we used a MANOVA. It was used to examine 1) differences in static and dynamic postural control between the experimental and control groups, 2) the difference between pre and post scores of both the stability index and LOS over time, and 3) the interaction effect between Groups and Time. If appropriate we ran a Repeated Measure ANOVA to determine any differences between groups at the post-test time point.

RESULTS

21 collegiate track and field athletes completed the pre-test session. Only 14 of the initial participants completed the post-test session. Of the 14 participants that completed the post-test none completed 100% of the training sessions, and only 10 participants completed 66% or more training sessions.

The means and standard deviations for the mCTSIB tests are Shown in Table 1. The MANOVA found no overall difference between the EO and EC Group ($F = .528$; $df = 5$; $p > .05$). or pre- and post-tests ($F = .1.581$; $df = 5$; $p > .05$). However, the between-subjects effects for the MANOVA found a significant difference between pre- and post-tests for the , eyes-open on foam condition ($F = 5.771$; $df = 1$; $p < .05$), and the overall stability index ($F = 4.661$; $df = 1$; $p < .05$). The Repeated Measures ANOVA was nonsignificant for Eyes-Open on Foam condition ($F = 4.153$; $df = 1$; $p > .05$)(Figure 1.) and overall stability index ($F = 3.873$; $df = 1$; $p > .05$)(Figure 2.).

Table 1. Means and SEM for mCTSIB Stability Index Scores

Condition	Group	Pre-Test	Post-Test
Eyes-Open Firm Surface	Eyes-Open	0.51 ± 0.11	0.51 ± 0.17
	Eyes-Closed	0.59 ± 0.21	0.40 ± 0.17
Eyes-Closed Firm Surface	Eyes-Open	0.97 ± 0.41	0.81 ± 0.20
	Eyes-Closed	0.83 ± 0.83	0.71 ± 0.20
Eyes-Open Foam Surface	Eyes-Open	0.82 ± 0.17	0.74 ± 0.13
	Eyes-Closed	0.90 ± 0.19	0.70 ± 0.06
Eyes-Closed Foam Surface	Eyes-Open	2.60 ± 0.72	2.45 ± 0.52
	Eyes-Closed	2.53 ± 0.50	2.00 ± 0.28
Overall	Eyes-Open	1.22 ± 0.26	1.13 ± 0.19
	Eyes-Closed	1.21 ± 0.22	0.95 ± 0.15

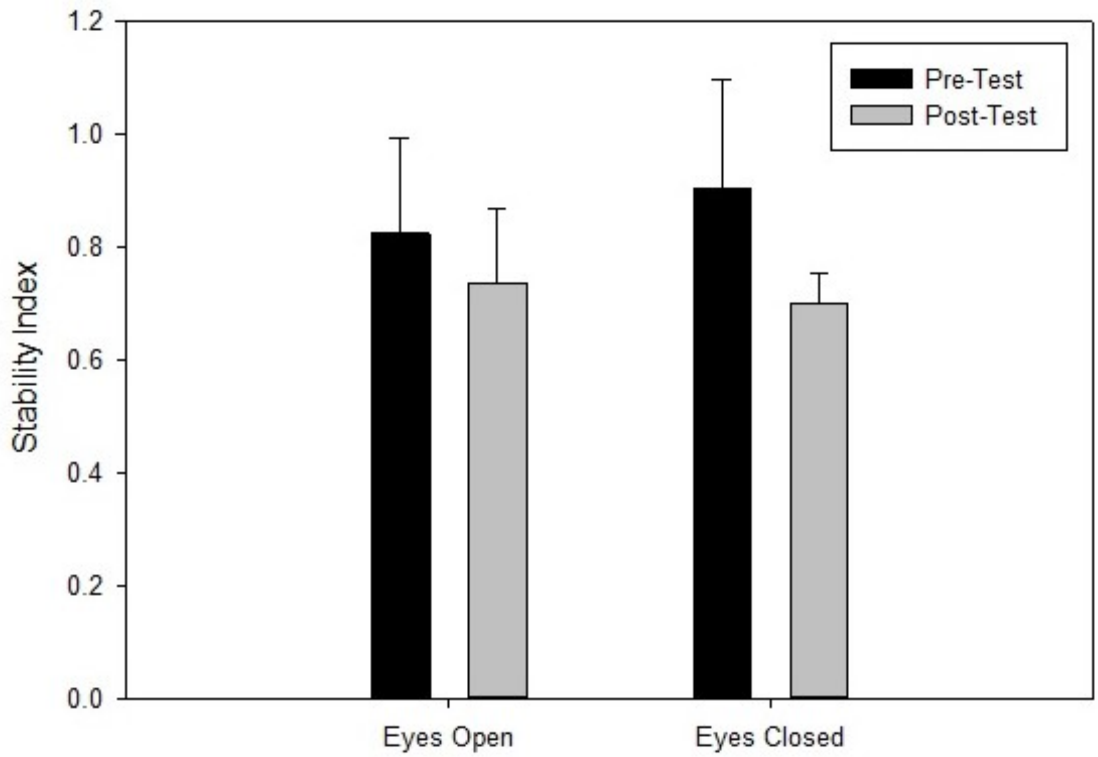

Figure 1. Average Stability Index Scores for Eyes-Open Foam Surface. Error Bars represent standard error of mean

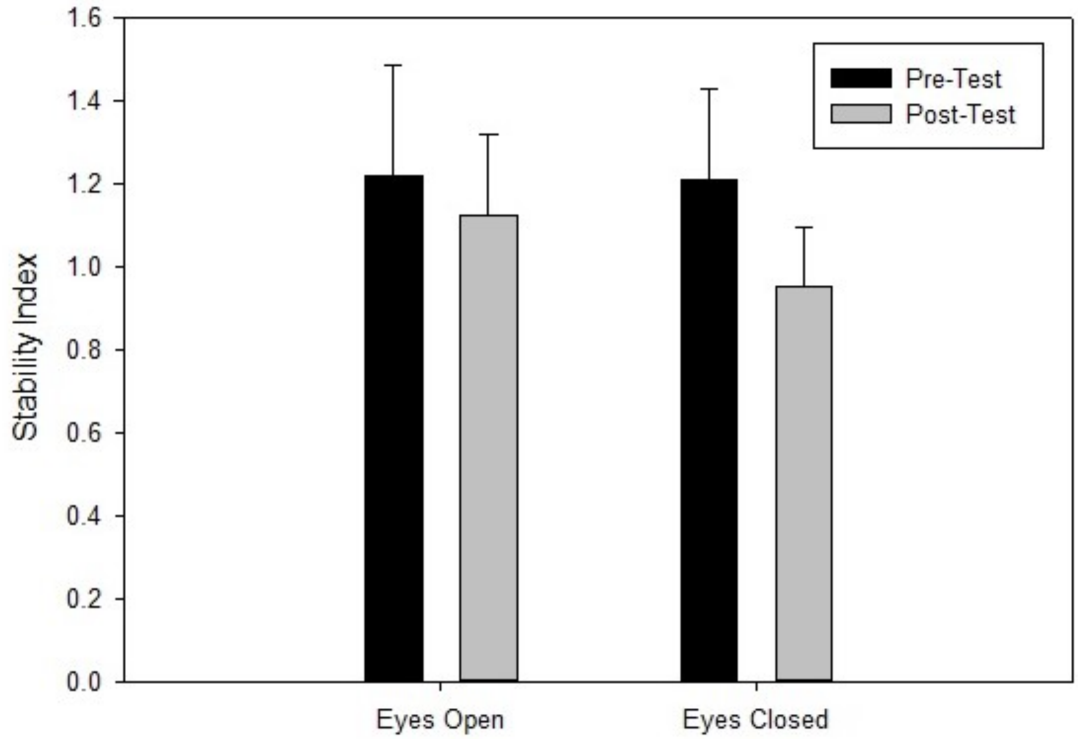

Figure 2. Average Overall Stability Index Scores. Error Bars represent standard error of mean

While the results show no significance difference between EO and EC training, there were some trends observed. From here we will describe the trends observed from the MANOVA and Repeated Measures ANOVA for mCTSIB. All four conditions and the overall stability index had improvement in stability index from the pre- to post-test. The EC group had more improvement then the EO group overall and in all conditions except the third condition, Eyes-Closed on a firm surface. The EC group also had the lower stability index at the post-test time point.

The means and standard deviations for the LOS test are shown in Table 2. The MANOVA found no overall difference between the EO and EC groups ($F = 1.611$; $df = 10$; $p > .05$) or the Pre and Post-test ($F = .987$; $df = 10$; $p > .05$). The between-subjects effects found a significant difference between groups for time ($F = 10.651$; $df = 1$; $p < .05$). The Repeated Measures ANOVA found between groups for Time to be nonsignificant ($F =4.448$; $df = 1$; $p > .05$)(Figure3.).

Table 2. Means and SEM for LOS Scores

Direction/Time	Group	Pre-Test	Post-Test
Time (sec)	Eyes-Open	52 ± 10	51 ± 12
	Eyes-Closed	44 ± 41	41 ± 05
Overall	Eyes-Open	56 ± 14	62 ± 16
	Eyes-Closed	63 ± 11	57 ± 05
Forward	Eyes-Open	53 ± 28	73 ± 14
	Eyes-Closed	65 ±21	55 ± 30
Backward	Eyes-Open	72 ± 24	61 ± 25
	Eyes-Closed	76 ±16	69 ± 34
Right	Eyes-Open	72 ±17	66 ±23
	Eyes-Closed	66 ± 18	72 ± 21
Left	Eyes-Open	63 ± 16	74 ± 22
	Eyes-Closed	63 ± 18	76 ± 21
Forward-Right	Eyes-Open	56 ± 18	70 ± 15
	Eyes-Closed	69 ± 21	58 ± 32
Forward-Left	Eyes-Open	61 ± 19	63 ± 27
	Eyes-Closed	71 ± 16	65 ± 24
Backward-Right	Eyes-Open	66 ± 15	57 ± 18
	Eyes-Closed	61 ± 25	60 ± 25
Backward-Left	Eyes-Open	58 ± 14	65 ± 24
	Eyes-Closed	75 ± 14	66 ± 21

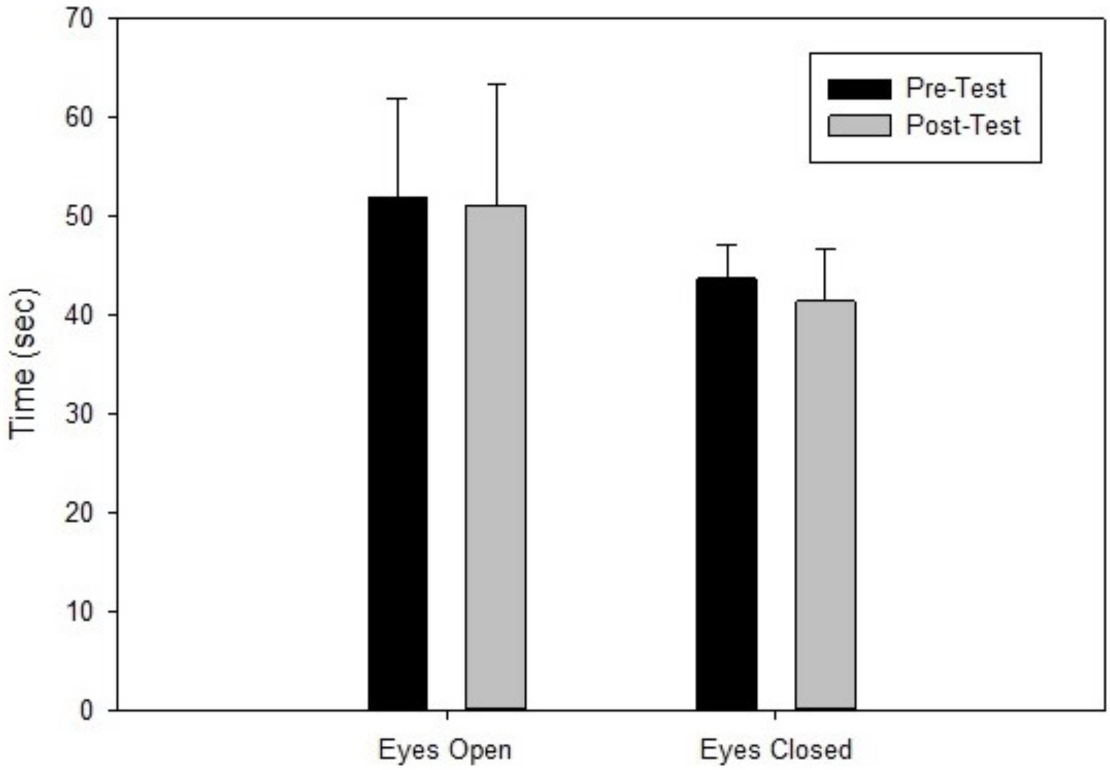

Figure 3. Average Time to complete Limits of Stability Test. Error Bars represent standard error of mean

DISCUSSION

The purpose of this study was to investigate if training postural control with eyes-closed would have the same effect as training with eyes-open on postural control. We found neither the eyes-closed or eyes open group significantly improved static or dynamic postural control after a 6-week postural control training program. We also found no significant difference between individuals that trained with their eyes-closed or eyes-open.

Finding no significant improvements in either static or dynamic postural control from the pre-test to post-test was surprising. It seems plausible that the lack of significance may be related to how the individuals were trained, conditions of training or timing. However, in previous studies investigating static postural control training, the training method did not matter as postural control improved regardless. Whether the training program involved altering support surface (Hoffman & Payne, 1995) or if vision was altered along with support surface (Yen et al., 2011), participants in both of those studies had improvement in postural control (Hoffman & Payne, 1995; Yen et al., 2011). It appears that the training method should not matter and individuals who undergo postural control training should see improvement.

It is also possible that we did not find significance in our study because the population investigated was delimited to healthy collegiate athletes. When athletes sustain an ankle injury and undergo conventional physical therapy, the addition of postural control training has shown to improve postural control ability(Chaiwanichsiri et al., 2005; McKeon & Hertel, 2008). Chaiwanichsiri et al. (2005) compared individuals that participated in a conventional physical therapy program for an ankle injury to individuals that participated in dynamic postural control training along with conventional physical therapy. The researchers found that the individuals who had the additional postural control training improved their postural control on the affected ankle more than individuals that underwent conventional physical therapy (Chaiwanichsiri et al., 2005). Showing the effectiveness of adding postural control training to physical therapy for individuals with ankle injuries. These findings are supported by McKeon and Hertel (2008), who showed that postural control training improved functionality and balance in injured populations. This improvement in postural control was also seen for stroke patients. Bonan et al. (2004) investigated the postural control ability of two groups of stroke patients. Both groups underwent the same postural control rehabilitation program, but one group did so with no visual information. They found that the individuals that trained without visual information had greater improvements in postural control (Bonan et al., 2004). Suggesting the effectiveness of eyes-closed training in improving postural control.

The improvement in postural control could be due to the individuals relying on visual information more than a typical healthy person to maintain postural control. After sustaining an ankle injury, individuals rely on visual information to maintain postural control (Kim, 2020). Allowing individuals to train these affected senses by eliminating visual information could possibly allow for more training adaptations, compared to healthy individuals training without visual information. With our participants being healthy, it is possible they relied less on visual information for postural control as compared to the injured or diseased groups in these prior studies and thus don't have the potential for as large of a training adaptation.

The design of training program used in our study could explain the lack of significance in postural control improvement overall and between groups. Hutt and Redding (2014) investigated an eyes-closed training program with elite ballet dancers. The training program was conducted by professional dance instructors, and once a participant improved postural control, they increased the difficulty of the training. Each participant started with the same level of difficulty but finished at different levels. The researchers showed that elite dancers can improve their postural control significantly with eyes-closed training (Hutt & Redding, 2014). This differs from our study as our participants did not improve postural control ability in either the eyes-closed or eyes-open group. Our training program, however, did not have a progression in difficulty for exercises. Participants did the same four exercises at the same level of difficulty throughout the whole intervention. It is possible that healthy athletes have a plateau in postural control ability, unless the intervention increases in difficulty.

The duration and adherence of our training program may also have not been adequate to see improvement in postural control. We designed a program that was two sessions per week for 6-weeks, total of 12 training sessions, as recommended by the systematic review published in *Journal of Athletic Training* (Zech et al., 2010). Unfortunately, due to unforeseen circumstances, participants only completed a total of 9 training sessions in the duration of the intervention. This number of total training sessions differs from studies that did see a significant improvement in postural control. Studies investigating healthy non-athletic individuals had a minimum of 12 sessions (Cox et al., 1993; Yen et al., 2011) and as many as 30 sessions (Hoffman & Payne, 1995). Studies investigating healthy athletic populations had 20 sessions (Hutt & Redding, 2014) to as many as 36 training sessions (Gioftsidou et al., 2006). The results of these prior studies suggest there is a minimum number of training sessions needed in order to achieve training adaptations for postural control training with non-athletic and non-healthy populations requiring less training sessions than healthy athletic populations. Thus, the low number of training sessions used in our study may help to explain why we only noticed trends in postural control improvement. We may have seen significant improvement if we trained longer than 6-weeks or had more than 9 overall sessions.

Limitations and Future Considerations

One limitation of our study was our number of participants and their adherence to the training program. At the pre-test date we had a total of 21 participants, with 11 in the eyes-open and 10 in the eyes-closed group. At the post-test date there was a total of 14 participants, with 10 in the eyes-open and 4 in the eyes-closed group. Thus, our study had a 60% drop-out rate for the eyes-closed group and 9% in the eyes-open group. Of the participants that completed the post-test date, only half of the participants completed 88% of the total training sessions available. The lack of adherence and drop-out rate could be due to the long duration of the program and low frequency of training sessions used. The low frequency could have caused participants to lose interest in the study and miss training sessions or drop-out completely. Studies that had training sessions as frequently as five days a week for four weeks saw higher adherence and participation (Bonan et al., 2004; Hutt & Redding, 2014). Both the higher frequency of sessions and duration of program could have both contributed to higher adherence and participation in study. While the duration of the training programs was shorter than ours, those studies had more total training sessions. Even with the reduced number of training sessions and large participant dropout rate, our results show a trend toward improvement in static postural control. Future studies should consider shortening the duration of the training program but increasing the frequency of training sessions to promote adherence and participation. Otherwise, if a future study uses a 6-week training program they should increase the frequency and total number of training sessions to maintain adherence and increase the likelihood of improvement in postural control.

To encourage adherence to the training program, we allowed participants to complete a postural control training session either before their track & field training or afterwards. Depending on when the participant completed our training session, fatigue could have played a factor. Ability to complete the exercises and to achieve any adaptations could be affected by when postural control training was performed. Giofsidou et al. (2006) found that individuals who complete balance training after regular soccer trainings had a larger improvement than individuals who completed balance training before soccer trainings in postural control. It is possible that the individuals who complete our postural control training after their track & field practice had a larger improvement in postural control, than those that completed it before. Future studies should consider the timing of postural control training and investigate whether postural control training is more effective before or after regular athletic trainings.

In this study, we investigated the effect of postural control training only in collegiate track & field athletes. Although postural control is important for most athletic activities, the ability and need for postural control varies substantially among different athletic populations (e.g. gymnast vs swimmer). We cannot conclude if our postural control training method wouldn't be effective for other athletic populations. Other athletic activities could benefit more from our training program due to the different demands of each individual activity. Future studies should consider investigating the relative effect of postural control training on different athletic populations.

In our study we chose to measure dynamic postural control with the Limits of Stability (LOS). The LOS is a reliable measure for dynamic postural control and was measured on a reliable instrument (Biodex SD Balance System). However, the LOS doesn't translate to athletic activities well. It only provides how far an individual can move their center of mass before they fall or need to make a biomechanical correction, such as stepping. Future studies should consider using Dynamic Postural Stability Index- (DPSI) with Time to Stabilization- (TTS). The DPSI with TTS involves having the individual single leg hop onto a force plate and maintain balance. Once the individual lands on the force plate the time to stabilize is taken as well as center of mass movement from the force plate. The DPSI is calculated similarly to how static postural control is measure with the McTSIB test, as it measures the amount of body sway (cm/s) an individual does as they try to stabilize. This DPSI test relates more to athletic activities, as it has the individual complete an athletic movement while also trying to maintain balance. Future studies should consider using the DPSI test if they want the postural control measure to resemble athletic activities.

CONCLUSION

The results of this study indicate that individuals that train postural control with their eyes-closed do not see a larger improvement than individuals who train with their eyes-open. While our study noticed a trend in individuals that trained with eyes-closed, had better postural control, this was not significant. This trend is promising, however more studies are needed to determine if training with eyes-closed is more effective at improving postural control than training with eyes-open. The results of our study indicate that neither eyes open nor eyes closed postural control training improves postural control over a 9 session/ 6-week training period. Nonetheless, clinically postural control training programs of sufficient frequency and duration may still be used to improve postural control and thus be used for rehabilitation or to reduce risk of future injury.

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