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The Effects of Balance Training on Stability and Proprioception Scores of the Ankle in College Students

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Abstract

Objective: The purpose of this study was to determine if stability and proprioception scores improved on college-aged students using a slack line device. **Methods:** One group of 20 participants aged 18-23 from a Midwestern university performed a pre-test/post-test on a computerized posturography plate to determine Center of Pressure (CoP) and Limit of Stability (LoS) scores. Participants performed three 20-30 minute sessions per week of balance and proprioceptive training using a Balance Bow for a period of four weeks. Data were analyzed (SPSS 21.0) using a dependent t-test to determine if any changes occurred between pre- and post-test scores after four weeks. **Results:** The analyses found no significance difference in Center of Pressure (CoP), normal stability eyes open (NSEO), normal stability eyes closed (NSEC), perturbed stability eyes open (PSEO), perturbed stability eyes closed (PSEC), or LoS forward (F), backward (B), or right (R) scores in college-aged participants. A significant difference was found in LoS left (L) and a notable trend towards significance was found in LoS R results. **Conclusion:** With the exception of LoS L stability scores, it was concluded that 12 sessions of 20-30 minutes, utilizing a slack line device, over a four week training period did not significantly improve stability and proprioceptive scores of the ankle in college-aged participants.

Keywords: Proprioception, Limit of Stability (LoS), Center of Pressure (CoP), slack line device

1. Introduction

Injuries are common in many sports, activities, and in daily living. They occur in varying degrees and in all areas of the body. Ankle injuries account for 27,000 injuries every day in the United States, making it the most common reported sports injury (Lynch & Renstrom, 1999). Most of these injuries happen in individuals under the age of 35 (Lynch & Renstrom, 1999) probably due to the intensity of the activity as well as levels of competition. Fried (2010) reported that 30% of individuals who sprain their ankle develop chronic ankle instability. Amrinder et al. (2012) identified other components that cause ankle instability, such as mechanical instability, ankle strength deficits, ligament deafferentation, and proprioceptive deficits.

Westcott, Lowes, and Richardson (1997) define postural stability as, “the ability to maintain or control the center of

mass (COM) in relation to the base of support (BOS) to prevent falls and complete desired movements". Balance is the process with which we maintain postural stability. Defined further, it is the ability to control postural stability (Alexandra et al., 2000). They are important factors contributing to the proper functioning of the ankle. A person's sense of balance is utilized in daily activities of daily living, but it becomes more important when engaging in activities that are more demanding than one's daily routine, such as playing weekend sports. Poor balance has been shown to increase the risk of ankle injury (Hrysomallis, 2007). Certain types of balance training has been shown to have a positive effect and decrease the risk of ankle injuries (Hrysomallis, 2007).

Postural stability and balance are vital components to the proper functioning of the ankle. However as previously identified by Amrinder et al. (2012), another physiological component that is constantly contributing to one's postural stability and balance is proprioception. Goldscheider was one of the first to systematically quantify the awareness of body segment positions and orientations, later defined as 'proprioceptions' and further explained this definition as a perception not necessarily perceived consciously but contributes to conscious sensations such as muscle sense, total posture, and joint stability (Amrinder et al., 2012). One primary reason for ankle instability, or lack thereof, lies in the functioning of the ankle's proprioceptors and communication with the brain. The central nervous system's (CNS) role is to deliver signals through the afferent neural pathways to produce awareness of limb, trunk, and head position and movement, which contributes to reflexive and cognitive motor skills (Shim et al., 2009). Past injuries due to developmental delays can result in slower synapses through the CNS. Scar tissue due to reoccurring injuries at particular joint sites such as the ankle with or without exostosis formation, and peroneal tendon tears have been shown to delay responses of the central nervous system (Amrinder et al., 2012).

Proprioceptive receptors of the ankle joint complex communicate with the brain, in order to confirm the position and motion of the ankle, and relay the correct motor response to the muscles to correct the perturbed foot in attempt to prevent injury. The application of an external force often occurs at a fast rate, so when this protective neurologic response is slow, an ankle injury may occur (Fried, 2010; Kandel, 2013). If neural adaptations do not occur to improve this response, the risk of re-injury is present (Houglum, 2001).

Effective methods have been found to improve the body's balance and proprioceptive abilities, and, therefore, helping to prevent or reduce the risk of injury (Amrinder et al., 2012; Emery, Cassidy, Klassen, Rosychuk, & Rowe, 2005; Hubscher et al., 2010; Hupperets, Verhagen, & van Mechelen, 2009; Lynch & Renstrom, 1999; Martinez-Amat et al., 2012; Shim et al., 2013). These studies have focused on the effects of various types of balance training, including proprioceptive training, to increase stability and reduce injury risk.

The slack line, a device with a piece of webbing strung between two points of attachment, is one such device. However, there is minimal research indicating its effectiveness in improving balance and proprioception. As slack line devices are becoming more popular for use in gym, fitness, and clinical settings, more research on the effectiveness of these devices is warranted. Therefore, the purpose of this study was to examine the effect of a four week program, utilizing the Balance Bow, on balance in a healthy, college-aged population. It was hypothesized that a four week program would have a positive effect on the balance scores of the participants. A one group pre-test, post-test design was selected to see if the slackline device was an effective tool towards improving proprioception scores on healthy college aged participants. This experimental one group pre-test, post-test design eliminated the use of a control group based on several studies conducted in the past using the Balance Bow (Shim et al., 2009; Shim & Crider, 2011) and demonstrating non-significance from a college aged subject group.

2. Methods

2.1 Subjects

20 participants aged 18-23 years from a Midwestern university were recruited for this study. The population included three males and 17 females (n=20). Five of these participants were Division One athletes compared to the rest of the sample size who were recreational participants. After approval for the study was granted by the Institutional Review Board (IRB), participants were recruited for the study. All participants were asked to sign an informed consent, a health status, and physical activity questionnaire to ensure the safety of the subjects, as well as give a subjective opinion about each participant's ankle stability. Participants were excluded from the study if a person did not attend the slack line training sessions, the pre- or post-test assessments, or 10 of the 12 intervention sessions over a four week period.

2.2 Instruments

A Bertec computerized posturography plate (Columbus, OH) was used to measure physical weight, Center of Pressure (CoP), and Limit of Stability (LoS) scores. The Bertec perturbed surface cover represented an unstable surface. The Balance Bow is a commercial slack line device manufactured by Ironwear Fitness Inc. (Pittsburgh, PA) that was designed to assist with improving balance. Exercises were performed on the Balance Bow with the participant's eyes open and closed in order to promote proprioceptive training. A stopwatch was used to record balance times for each subject.

2.3 Procedure

Each subject performed a pre-test to determine a baseline score on the Bertec balance plate for CoP NSEO, NSEC, PSEO, PSEC, and LoS R, L, F, B. Participants stood on the balance plate with both legs at the appropriate foot markings with arms relaxed and at their sides and were assessed on their normal stability CoP with their eyes open,

according to the manufacturer's protocol. The next measurements consisted of the eyes closed, in order to provide information about the individual's proprioception. Participants were also assessed on CoP and LoS scores using a perturbed surface. Each participant was given the same exact instructions during the pre-testing procedure, prior to having data collected. Following the pre-test, each participant took part in a balance training program using the Balance Bow. A four week intervention program was designed to work on balance and proprioception skills, and focused primarily on the ankle joint and lower extremities. During the training session, participants were shown how to properly do each exercise, practiced them before being on the slack line device, and asked any questions they had about the intervention program.

Participants engaged in three specific exercises on the Balance Bow that included the power line, tight rope, and single leg standing drill. The power line exercise involved the participant standing with both feet perpendicular to the slack line and maintaining equilibrium as long as possible. The tight rope involved participants standing and balancing with both feet parallel to the slack line device with one foot in front of the other and also held to maintain equilibrium as long as possible. The front foot was alternated with each exercise to create equal training effects during each session. The single leg exercise involved the participant balancing with one foot perpendicular to the slack line while using the other leg as a counterbalance. Participants attempted to maintain equilibrium in these positions for as long as possible and recorded their balance times in seconds. At least five repetitions of each exercise were attempted per training session. Two additional repetitions of each exercise were attempted with eyes closed. A spotter was available to prevent the participant from injuring themselves during the drills. Participants were asked to perform these exercises three days a week for four weeks under the supervision of one of the investigators. Training sessions were spaced at least 24 hours apart. Participants resumed their normal daily activity level in addition to performing the balance training sessions.

After the four week balance and proprioceptive training intervention with the Balance Bow, participants performed a post-test using the same exact protocol as the pre-test on the Bertec balance plate. Differences in CoP (NSEO, NSEC, PSEO, PSEC) and LoS (R, L, F, B) scores were assessed using a dependent t-test ($p < .05$). SPSS (version 21.0) was utilized to analyze the results.

Table 1. Descriptive Statistics (n=20)

	Mean	Std. Deviation	Range Lower	Range Upper
Age	19.90	1.6827	18.00	23.00
Body Weight (kg)	70.58	12.60	54.10	92.74
Height (cm)	169.67	1.43	24.40	29.90
CoP				
NSEO	-0.0850	2.9948	-1.4866	1.3166
NSEC	1.1500	4.0283	-0.7353	3.0353
PSEO	0.2300	2.8720	-1.1141	1.5741
PSEC	-1.4850	6.5411	-4.5464	1.5764
LoS				
F	2.7100	24.5737	-8.7909	14.2109
B	-13.2150	36.8037	-30.4396	4.0096
L	-26.3300	41.5803	-45.7902	-6.8698
R	-18.6100	41.4209	-37.9956	0.7756

3. Results

Descriptive statistics are summarized in Table 1. No significant differences were found in CoP NSEO, NSEC, PSEO, PSEC, LoS F, and LoS B. A significant difference was found in LoS L and there was a trend towards significance with LoS R (see Table 2). Figure 2 showed the pre- and post-test means of all scores measured. The LoS L and R scores are significantly higher than all other scores shown. Still, the LoS L scores had the greatest amount improvement. While most of the data did not show significant differences in the change of stability scores at $\alpha < .05$, there were changes in mean differences worth noting. Mean differences increased between the CoP pre-test PSEC (M= 87.740) and post-test PSEC (89.225), as well as LoS pre-test (M= 65.565) and post-test (M= 78.780). While not significant, improvement in balance and stability scores were observed based on the resulting trend seen in Figure 1.

Table 2. Significant Values

	t-value	p-value
CoP		
NSEO	-.127	.900
NSEC	1.277	.217
PSEO	.358	.724
PSEC	-1.015	.323
LoS		
F	.493	.628
B	-1.606	.125
L*	-2.832	.011
R**	-2.009	.059

*Significant at the 0.05 level

**Trending towards significance at the 0.05 level

Additionally, worth noting are the differences between the LoS R and L results. A significant improvement was found between the pre-test and post-test LoS L (p= .011). While not significant, a notable improvement in the mean was found in pre-test R (M= 133.165) and post-test R (M= 151.775). This suggests that balance training performed on the Balance Bow primarily helped improve right and left stability scores. This may be due to the observable differences noted in the single leg balance exercises performed during the balance training intervention. Differences between the first and last sessions in the right and left single leg standing exercise training mean times are shown in Table 3.

Table 3. Training Differences in R and L Means (n=20)

First Session	Mean (sec)	Last Session	Mean (sec)
Right	6.685	Right	14.476
Left	8.566	Left	14.825
Eyes Closed Right	2.33	Eyes Closed Right	2.613
Eyes Closed Left	2.328	Eyes Closed Left	2.655

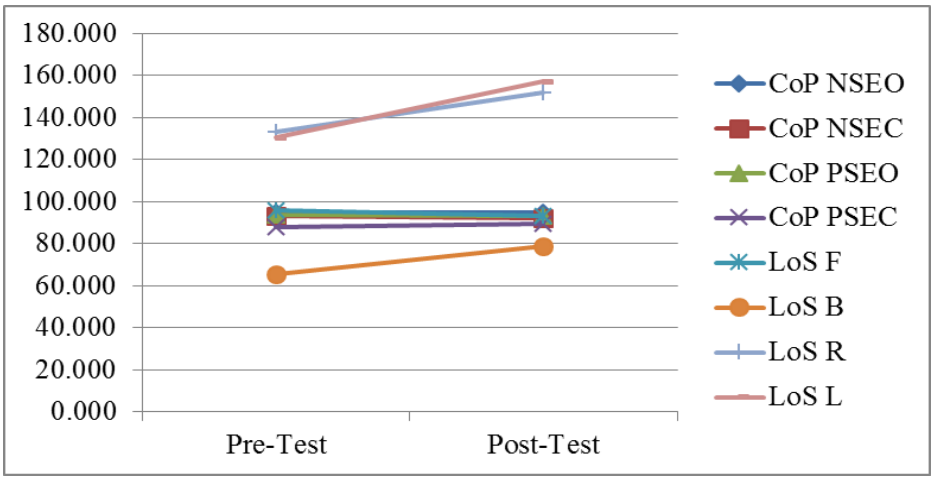

Figure 1. Pre & Post Test Means

4. Discussion

The improvements in single leg stance is important because the majority of ankle injuries are inversion sprains, which often occur in the frontal plane and deal with lateral ankle stability (Lynch & Renstrom, 1999). With improvement in these areas, the risk of ankle injury could be greatly reduced due to the study findings. Changes in the other variables investigated may not have occurred due to a ceiling effect. First of all, five of the subject participants were Division I

athletes. The remaining participants were physically active four or more days of the week and/or involved in intramural sports. A minority of the participants, only four of the 20, were inactive or active less than three days of the week. Due to the high involvement of physical activity and training in the majority of subjects, the margin for change and improvement of scores may have been minimal compared to those individuals who were not as physically active as their fellow participants. If significant improvements were made for a few of the non-active individuals in this study, they may have been masked due to the minimal ability for change in the majority of individuals demonstrating higher physical activity involvement.

The training intervention protocol, developed from recommended exercises performed on the Balance Bow by Ironwear Fitness manufacturers, may not have been adequate for noticeable changes to occur. The training intervention consisted of 20 - 30 minute sessions performed three times a week for four weeks on the Balance Bow Previous studies have seen significant changes in balance abilities when the training protocol lasted longer than four weeks (Amrinder, 2012; Emery et al., 2005; Hrysomallis, 2007; Hupperets et al., 2009; Linford et al., 2006). Although Emery et al. (2005) found significant changes in balance abilities by requiring daily training sessions lasting only 20 minutes, other studies, in which significant balance improvement have been noted, required participants to engage in 30 or 40 min sessions (Amrinder et al., 2012; Hupperets et al., 2009; Linford et al., 2006). Therefore, the training protocol in this study may not have been appropriate for significant changes in stability and proprioception to present themselves within this population.

There are many other factors that can affect balance, such as vestibular imbalance, sinus congestion, prior surgeries, injuries, weakness, etc. While we were aware of these components, they were not taken into account in this study. They may or may not have contributed to differences in the hypothesized results. Future studies should investigate the differences in stability scores after a period of balance training on a slack line device between individuals with high physical activity involvement and individuals with low physical activity involvement. Differences found in these studies could be meaningful to determine if certain populations are more susceptible to changes in stability compared to others. Additional studies should also examine populations who often have decreased balance and proprioception due to reduced functionality and a compromised CNS, such as older adults or those who are at risk for ankle injuries or children with delayed movement issues. Furthermore, additional studies should focus on the appropriate modes, duration, frequency, intensity of various slack line exercises in order to create “best practice” protocols for preventing ankle injuries for various populations. While this study did not investigate balance differences in gender, other studies have found that girls have a better sense of balance than boys (Lee & Lin, 2007; Nolan et al., 2005; Odenrink, 1984; Peterson et al., 2006; Seco et al., 2012; Smith et al., 2012). Therefore, training protocols for a slack line device may need to differ based on age, gender, and other variables.

5. Conclusion

A four week period of balance and proprioceptive training on a slack line device was found to have no significant effect on CoP NSEO, NSEC, PSEO, PSEC, or LoS F, B, or R scores in college aged participants. A significant difference was found in LoS L and a notable trend towards significance was found in LoS R results. Due to the fact this is the only known published study that has investigated training effects of balance and proprioception utilizing the Balance Bow, future research is needed to determine the accuracy of these findings. Additional studies, with various populations, examining longer balance training periods, session durations, intensities, or session frequencies could reveal best practice protocols for improving balance and proprioceptive abilities, and, thus, reducing the risk for an ankle injury.

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