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Unilateral Balance Training of Noninjured Individuals and the Effects on Postural Sway

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The purpose of this study was to provide normative data on postural sway by comparing the mean gain score between two balance training groups and a control group. Twenty-seven recreational collegiate athletes (14 females, 13 males, 18–36 years old) with no past documented lower extremity injury or lesion of the vestibular system were randomly placed into three groups: control (nontraining), foam surface training, or hard surface training. The Chattecx Dynamic Balance System (CDB) was utilized for objective post- and pretraining recordings. CDB tests were performed on the training and nontraining extremities with subjects' eyes open and eyes closed. Results revealed no significant post to pre mean gain score differences within any group, nor was any significance revealed between group differences. Although no significant differences were revealed, trends indicated specificity of training toward testing mode. These data should assist clinicians in preventing ankle injury or compensating for ankle instability with balance training.

Ligamentous injuries of the foot and ankle produce proprioceptive deficits affecting the muscles of the injured leg (4, 12). Proprioception is defined as "the awareness of postural movement, the changes in equilibrium, and the knowledge of position, weight, and resistance of objects in relation to the body" (11). Proprioceptive information arises from mechanoreceptors in the skin, muscles, tendons, joint capsule, and ligaments. It includes information concerning static position, movement, and muscular forces. This information is relayed to the central nervous system (CNS) and back to the effector muscles (1, 14), which reflexively assist in controlling joint position.

Injury to the ankle may affect its mechanoreception, resulting in abnormal input to the CNS (13). Many articular nerve fibers terminate in mechanoreceptors within the capsule and ligaments about the ankle. They respond to changes in joint position, acceleration, and direction of movement. Injury to the ankle may lead to partial joint deafferentation, thus interfering with proprioceptive reflexes

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that are mediated by articular mechanoreceptors. Deficits in proprioception may adversely affect postural sway (4).

Glencross and Thorton (7) found a linear trend between the degree of error and joint angle, with the largest error occurring at the largest angles of movement. They also found that the error was the greatest for individuals with second and third degree ankle sprains. Garn (6) found that the total number of mechanoreceptors decreased through repeated trauma. Therefore, fewer mechanoreceptors are available to react when the terminal joint positions are reached, thus resulting in increases in the degree of error or postural sway (7). Tropp et al. (12) utilized force plate measurements to test subjects with injured ankles by having subjects complete a modified Rhomberg stance test on the injured and noninjured extremities. No significant differences in postural sway were observed. Based on the findings of Freeman and Dean (4), it has been speculated that the proprioceptive deficit can be substantially reduced if balance training is incorporated with a strengthening program during postinjury treatment.

Mechanoreceptors play a role in the fundamental organization of the CNS. Acting as transducers, they convert physical energy expressed as tension into a nervous signal (14). There are four types of joint mechanoreceptors located in and around joints. Type I joint receptors are encapsulated Ruffini-like structures located in the superficial layers of the joint capsule. They are slowly adapting; thus they respond to pressure changes within the joint, and they signal static and dynamic tensile stresses (14). These receptors provide the CNS with information in resting and active conditions. Type II joint receptors are encapsulated Pacinian-like structures located in the deep fibrous layers of the joint capsule. They are rapidly adapting and have a low threshold for activation (5, 10). They are dynamic mechanoreceptors that signal acceleration during passive or active movements. Type III or Golgi tendon organ–like receptors are located in the joint ligaments. They have a high threshold for activation and are slow adapting. Type III receptors are active at the end ranges of joint motion. Type IV receptors are encapsulated free nerve endings and are found in the ligaments and joint capsule. These are pain receptors that respond to extreme mechanical or chemical irritation.

Postural stability can be defined as "the body's ability to maintain equilibrium at rest or during motion" (9). Postural stability is dependent on the complex reflex mechanisms involving vestibular and visual and mechanoreceptor input.

A number of balance training protocols are presently being utilized for rehabilitative testing and research. The Chattecx Dynamic Balance System (Chattanooga, Tennessee, 1990) used in this study provides the clinician with objective recordings in unilateral balance testing because it uses a force plate and computer printout. In regard to balance training, however, specific techniques, modes, duration, and frequency are not scientifically based. The modified Rhomberg Test drill (stork stand), on a hard surface or a foam surface, is frequently utilized in most training rooms due to convenience and lack of expense. There is very little information regarding the efficacy of this training method. In this study, which used the modified Rhomberg stance, it was postulated that improvements in proprioceptive feedback would occur with adequate stimulation. It was hypothesized that a 4-week progressive balance training program, utilizing a hard surface or a foam surface, would (a) result in a decreased standard deviation in postural sway compared to a control group, (b) produce a larger decrease in postural sway in the foam training group than in the hard surface group due to the limited challenge presented by the hard floor, and (c) result in no significant difference in the post- and pretraining testings in the eyes open and eyes closed groups. Noninjured subjects were used for this study to demonstrate training effects on uninjured extremities and to create a base for future research using subjects with previous injury. The present study was undertaken to help clinicians design more effective functional rehabilitation programs that stress kinesthetic sense and ultimately decrease or prevent ankle instability among athletes.

Methods

Subjects

Twenty-seven recreational male (n = 13) and female (n = 14) athletes (ages 18–36) were recruited for this study. *Recreational athlete* was defined as an individual who exercised regularly but did not take part in organized competition. The protocol was approved by the Biomedical Internal Review Board for Biomedical Research of the University of Pittsburgh, and all subjects signed a written consent form outlining the risks of the study. None of the subjects had prior documented lower extremity injury or lesion of the vestibular system. The subjects had no prior experience with the CDB or any other balance training techniques. The dominant extremity was utilized for the training limb. We established dominance by asking each subject to identify the leg he or she would use to kick a ball.

Each subject was randomly assigned to one of three treatment groups: a control group (no training), a foam surface group (treatment A), or a hard surface group (treatment B). The preliminary analysis of the data demonstrated no significant differences among the groups. A BMPD Statistical Software program was used. The statistical design used to test for treatment differences was a three-way analysis of variance (ANOVA) (Group × Limb × Eye).

Chattecx Dynamic Balance System

The Chattecx Dynamic Balance System (CDB) was designed to measure postural stability and was used to objectively assess post- and pretraining balance for all subjects. The reliability of measuring postural sway during unilateral stance in normal subjects was confirmed in an unpublished study (2). The CDB consists of four independent force-measuring transducers and is used to quantify postural stability. Fluctuations in displacement of the center of pressure reflect the amount of postural sway. The dispersion index, or sway index, was calculated as the standard deviation around the mean of 100 data points per second during a 10-s test. Differences in the limits of postural stability between the involved and noninvolved extremity, and in regard to joint and ligamentous instability, have been noted in several unpublished balance training studies (3, 8).

Testing Procedure

CDB Post/Pretesting

The software used to operate the CDB was programmed through Keytouch Software Technology. Testing was performed with subjects in a unilateral stance on the force plate; dominant and nondominant extremities were tested in random order. Subjects were barefoot for all testing and training procedures. Each subject's foot was centered on the foot plate. The "ball" (metatarsal heads) of the foot was placed on the marked area on the anterior plate. The length of the heel plate was adjusted so that the calcaneus was bisected by the posterior marked area. The graph coordinates of the foot were entered into the system so that the force plates could monitor the weight distribution accurately. This information was stored for posttesting. A viewing monitor was directed away from the subject so it would not provide visual input (see Figures 1 and 2).

The recordings were made with each subject standing with the dominant knee extended (0°), the nondominant knee held at a 90° angle, and the hip in neutral position. Posture was maintained erect, the arms were crossed, and the hands touched the opposite shoulder. Each subject donned a safety harness to avoid injury from falling. Test recordings began when the subjects indicated they perceived they were balanced. Each subject stood in bilateral support between each test to avoid added fatigue. Each test was performed for 10 s.

Figure 1 — Example of subject on Chattecx Dynamic Balance System while testing.

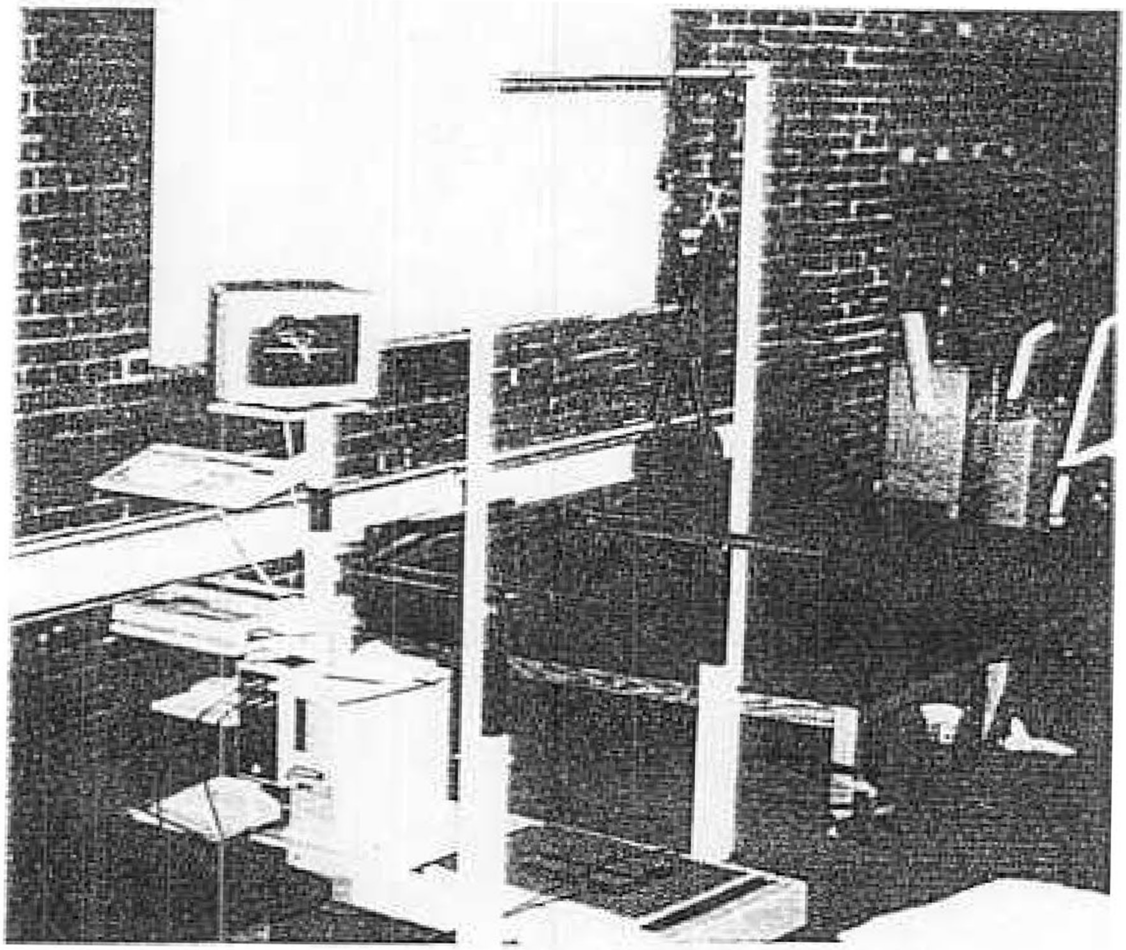

Figure 2 — Example of Chattecx Dynamic Balance System.

Training Surfaces

Subjects in treatment group A used a foam surface that was 3 in. × 18 in. × 18 in. and was of medium density. Subjects in treatment group B used a hard, smooth tile floor.

Treatment Protocol

The training protocol for the foam and hard surface groups was the same. Subjects trained over a 4-week period, three times a week, for 5-min sessions. During each training session, each subject had eyes closed and stood barefoot on the dominant leg with arms crossed over chest and the nondominant knee maintained in a flexed position. The nondominant knee was flexed to midrange (45°) the first 2 weeks and then progressed to a right angle (90°) for the last 2 weeks. Balance training was not allowed for the control group during the 4-week period.

Results

The results indicated no significant differences ($p < 0.05$) in the mean post/pre gain scores (see Table 1). No significant differences in the mean gain scores were revealed among the three groups when subjects were tested with eyes open and eyes closed (see Figures 3–6).

Table 1

Three-Way ANOVA Summary Table for Balance

Source	D.F.	Mean square	*F*	Tail prob.
Group	2	91.21124	2.45	0.1075
1 Error	24	37.21838		
Trained	1	88.66905	4.57	0.0429
TrG	2	23.70998	1.22	0.3121
2 Error	24	19.38856		
Eyes	1	59.70581	3.36	0.0793
EG	2	19.40169	1.09	0.3518
3 Error	24	17.77558		
TrE	1	64.96745	2.95	0.0988
TrEG	2	21.02359	0.95	0.3992
4 Error	24	22.02886		

Note. Tr = trained; E = eyes (opened/closed); G = group (hard/foam/none).

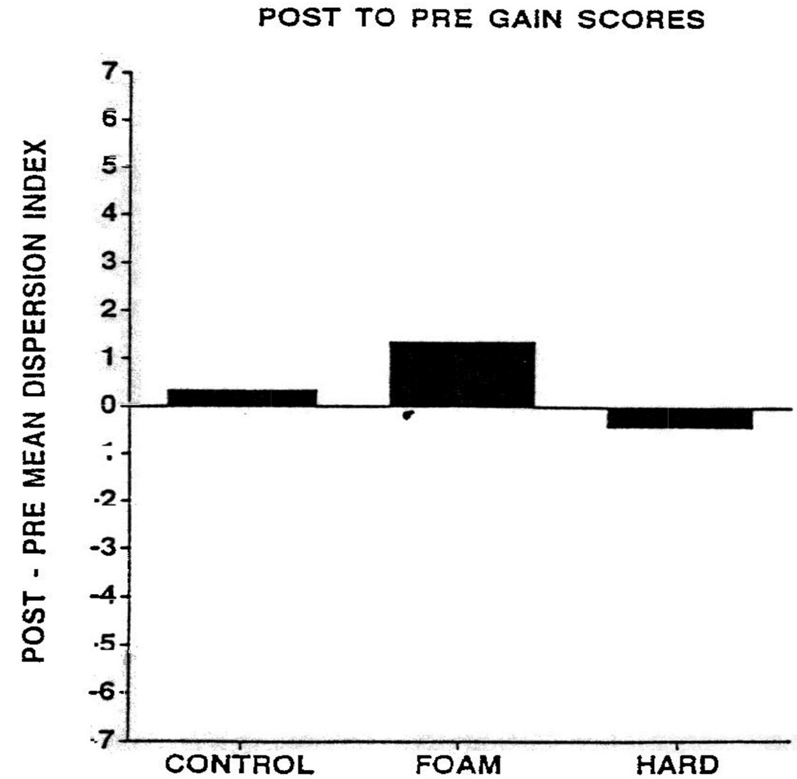

Figure 3 — Post/pre mean gain score for each group on the training leg/eyes open condition. In Figures 3–6, lower or negative values represent improvements in balance.

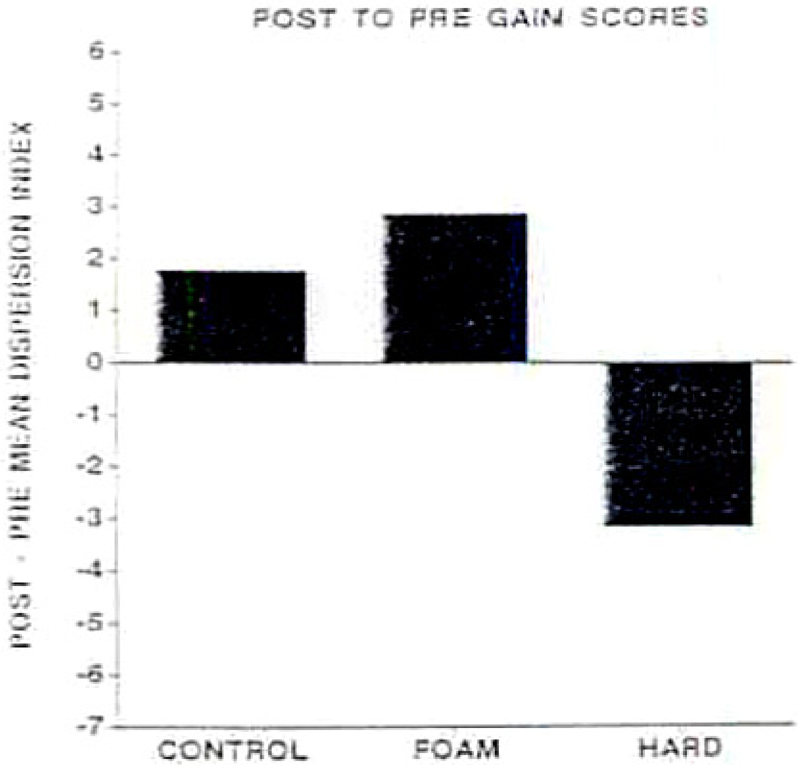

Figure 4 — Post/pre mean gain score for each group on the training leg/eyes closed condition.

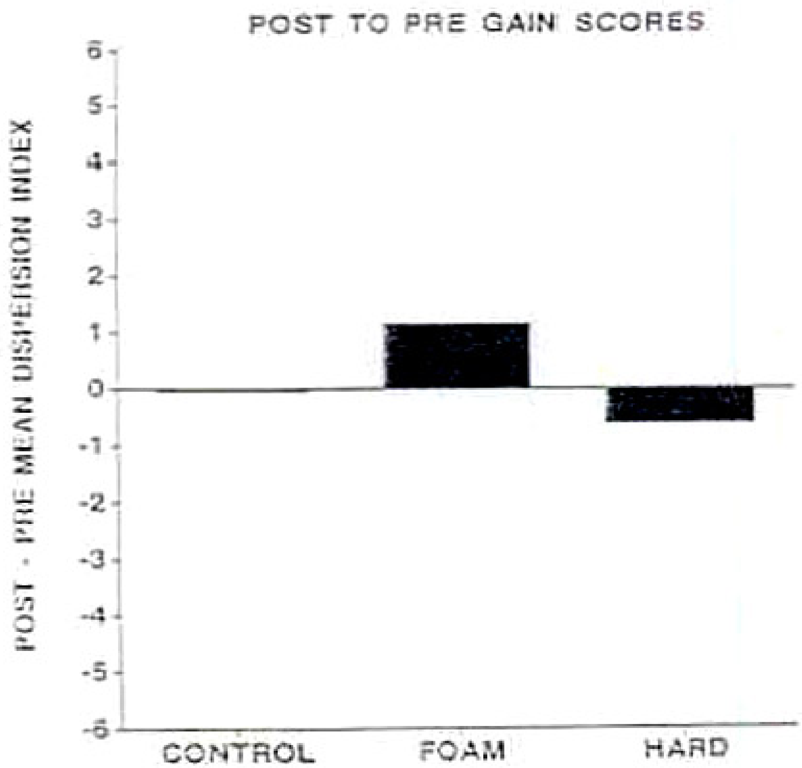

Figure 5 — Post/pre mean gain score for each group on the nontraining leg/eyes open condition.

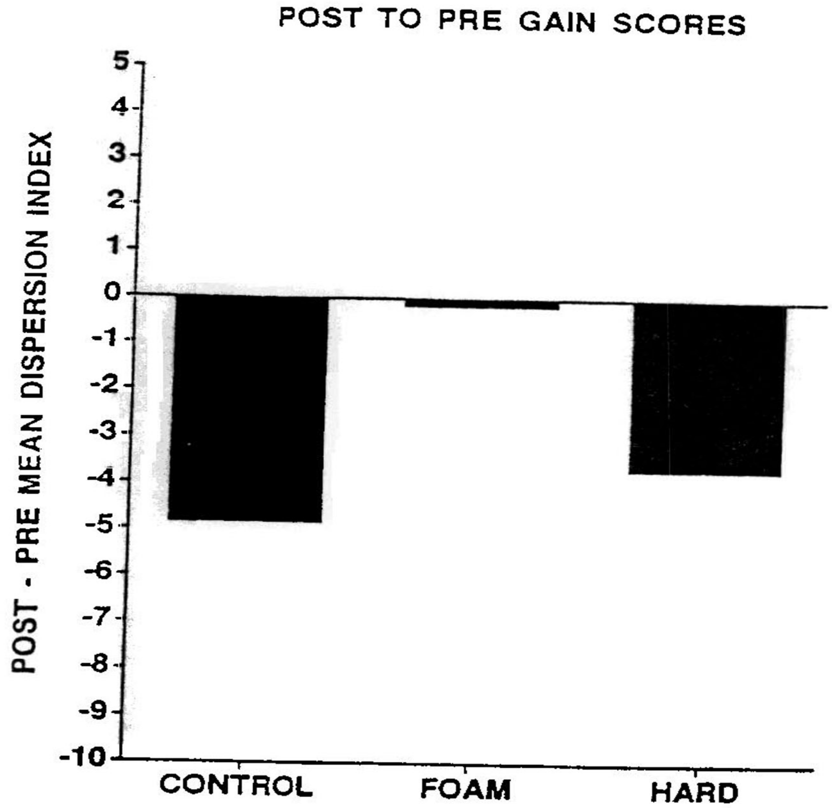

Figure 6 — Post/pre mean gain score for each group on the nontraining leg/eyes closed condition.

We analyzed the data by viewing post/pre scores instead of pre/post scores to demonstrate the changes in postural sway. A negative result indicated a decrease in the amount of sway, thus an improvement in balance. A positive result showed an increase in sway, therefore a regression of balance control.

Discussion

The present study examined the effects of balance training on postural sway. The results of this study revealed no significant post to pre mean gain score differences within any group, nor was any significance revealed between group differences. However, an interesting trend was noted in the results: The hard surface group revealed a consistent improvement in all four test measurements on the Chattecx Dynamic Balance System. Implications may be drawn from this information. First, the consistent pattern of decreases in postural sway post/pretest may indicate enhanced awareness of postural sway in the trained extremity, thus a potential step toward injury prevention. Noninjured subjects were trained and tested so we could view the changes that occur in a controlled setting in the absence of a pathology. Due to the lack of knowledge in the field of proprioception, these baseline findings in noninjured subjects are valuable for future comparison with athletes who have ankle injuries. We were unable to apply the results observed in this study to clinically defined "normal" subjects. Future study in this area is urged.

Second, the results showed postural sway improvements in the hard surface training group. This may simply be due to the fact that the training surface and the testing surface were similar. There were no large or consistent improvements in the foam surface training group. However, decreases in post/pretest postural sway results may have been evident if the testing surface had been foam instead of a hard surface. There were limitations in using the foam on the force plate, and therefore viewing test surface differences between treatment groups was not possible. Another factor in the improvements in the hard surface training group was training control. Subjects stated that the hard surface provided a stable base and allowed for efficient balance training, with minimal opposite extremity surface touchdown. This group stated the training "felt easier" with each session. Subjects in the foam surface group subjectively stated that there was no decrease in the challenge of balancing. These subjects complained of frequent loss of balance and no decreases in touchdown times. It is possible that the medium-density foam surface was too advanced for initial balance training. A higher density (allowing less deformity) foam may be necessary to provide the subject with a stronger base to begin training, prior to progressing to a more pliable surface.

Numerous protocols are used for balance training. The unilateral Rhomberg stance method for training was examined in this study due to its universal application in rehabilitation settings. This method is easy, can be implemented into home programs, and can be used by athletes who do not have access to optimal training equipment (e.g., when traveling). The results of this study may be due to the training protocol and not to the training or testing surface type. Perhaps 5-min unilateral training sessions are too demanding on the involved structure. Shorter training sessions may increase the quality of training.

Due to the fact that noninjured subjects were utilized in this study, results cannot be directly applied to the injured athlete. Due to the arrangements of mechanoreceptors in the ankle, if there is no trauma disrupting the arrangement of these receptors, there may or may not be room for improving their awareness. These are some points that must be addressed in future studies.

Summary

The findings of this study reveal the need for clinicians to explore balance training. Additional information provided from future research in the area of kinesthetic training will allow for a more effective functional rehabilitation program.

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