Effects of a 6-Week Strength and Proprioception Training Program on Measures of Dynamic Balance: A Single-Case Design

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Objective: To examine the effects of a 6-week strength and proprioception training program on clinical measures of balance, and to introduce characteristics of a single-case research design that may be beneficial to the athletic training profession as both a research and a clinical tool.

Design and Setting: A multiple baseline design across subjects was used to assess the effects of the intervention. The training program was performed three times a week and consisted of manual muscle strengthening and proprioception training for the plantar flexor, dorsiflexor, inversion, and eversion muscle groups.

Subjects: Three subjects (age = 17.6 ± 1.24 yr, wt = 78.6 ± 1.07 kg, ht = 186.2 ± 4.3 cm) who had previously sustained first-degree lateral ankle sprains.

Measurements: Dynamic balance was tested three times a week using a single-plane balance board (SPBB). Each subject was tested for two double-leg conditions (forward/backward, right/left) and one single-leg condition (forward/backward) for each extremity. The dependent variable was the number of times that the balance board made contact with the floor. Visual inspection was used to evaluate whether the treatment resulted in a change of performance.

Results: Although the intervention did not produce obvious improvements in balance for all evaluation criteria for all testing conditions, it is apparent that the strength and proprioception training program positively influenced all three subjects' ability to balance dynamically on an SPBB. A change in mean scores from baseline to intervention phase was evident for all testing conditions. However, a change in slope and level was not as apparent for all testing conditions, especially the single-leg conditions.

Conclusion: The results revealed that the strength and proprioception training program produced improvements in the ability to balance as assessed dynamically on an SPBB.

Key Words: ankle sprain, postural sway

A rehabilitative program integrating strength and proprioception concepts is common when treating lower extremity injuries.[1-3] Although functional implication for improving proprioception following injury to structures of the lower leg is still being examined,[3-7] proprioception training is often indicated following injury to the lower extremity. Proprioception (somatosensation) is a distinct component of balance. It is the cumulative neural input to the central nervous system from the mechanoreceptors in the joint capsules, ligaments, muscle tendons, and skin.[8] When these structures are subjected to mechanical deformation, action potentials are conducted to the central nervous system (CNS), where the information can influence muscular response and position sense. The integration of afferent neural input to the CNS contributes to the body's ability to maintain postural stability.

Deficits in proprioception are commonly evaluated with static measures of balance, such as the modified Romberg test, or with dynamic measures of balance assessed with computerized force platforms.[9-13] The expense of such computer-assisted evaluation limits the use of these tests with a broader population. We used a single-plane balance board (SPBB) to assess dynamic balance because of its affordability and ease of use.

Our purposes were to evaluate the effectiveness of a 6-week strength and proprioception training program on the ability to improve dynamic balance and to introduce characteristics of a single-case research design that may be beneficial to the athletic training profession as both a research and a clinical tool.

Single-case experimental designs offer a research approach that closely mimics a typical rehabilitation process. For example, the athlete reports to the athletic trainer with a problem. As clinicians, we identify a disorder and then offer an intervention. The identification of a problem is similar to establishing a baseline. As the athlete returns for treatment we continue to reevaluate and then proceed with the current treatment or, maybe, alter our treatment. The repeated measurement and interventions that we use in everyday practice offer an ideal arrangement for performing single-case examinations.

Single-case design, to our knowledge, has not been reported in the athletic training literature. A single-case or single-subject experimental design is characterized by the following: identification of a baseline measure, repeated measurement of the dependent variable, repeated manipulation of the independent variable, a comparison within the individual across differing conditions, one or a few subjects, a replication of effects, and, ideally, a measurement that is objective.[14] In contrast, case studies are frequently reported in the athletic training literature and are considered a prescientific mode of

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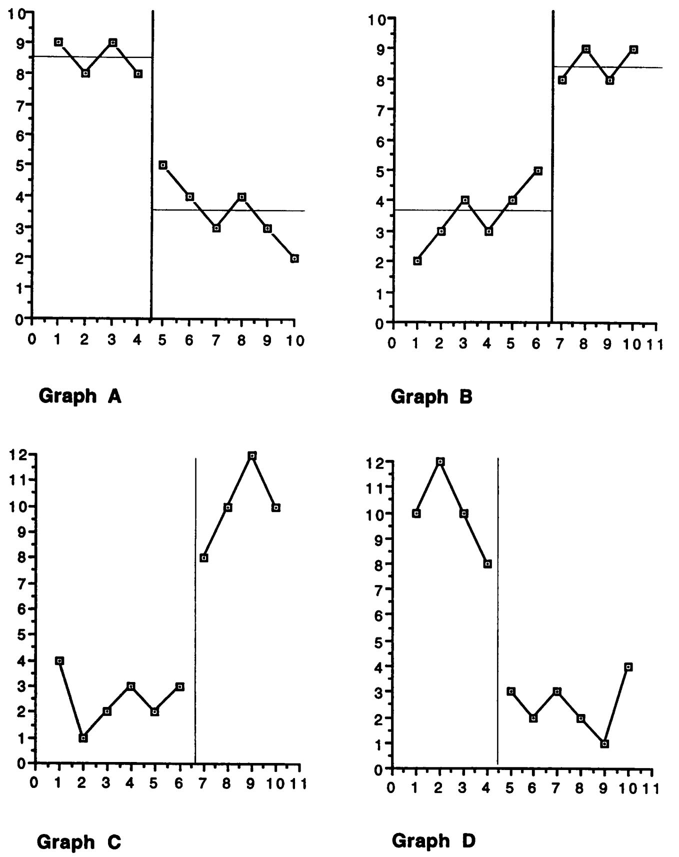

Fig 1. Visual representation of a change in means (graphs A and B) and a change in level (graphs C and D).

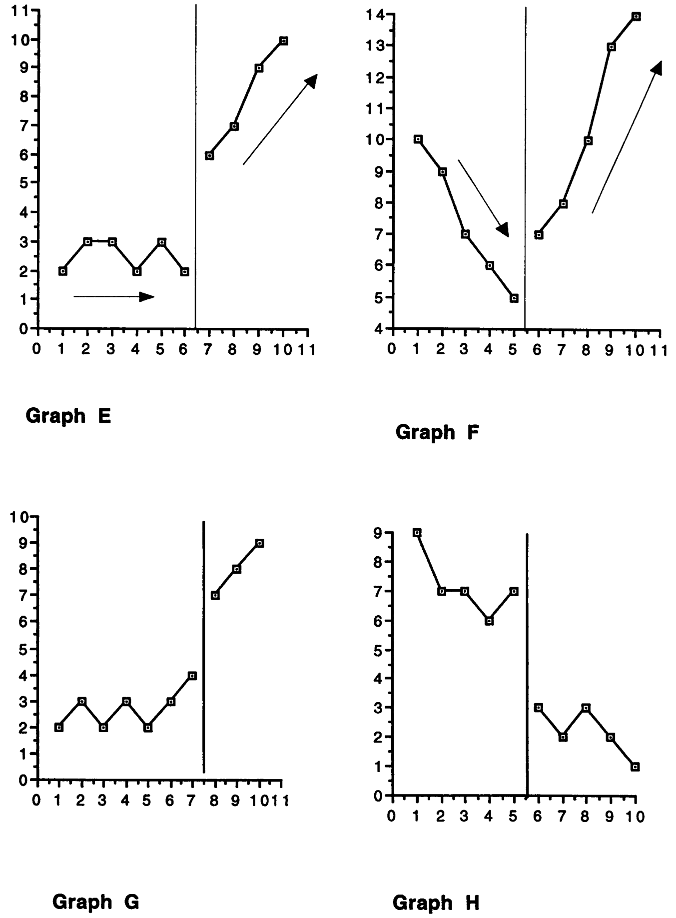

Fig 2. Visual representation of a change in trend, or slope (graphs E and F), and latency of change (graphs G and H).

reporting findings.[15] Case studies are not classified as experimental designs because they lack controls that would eliminate or minimize other possible sources of variations.[15] Case studies document clinical findings without controlling the independent variable in a stringent manner.

Single-case designs are most commonly evaluated by examining the effects of the intervention over time using visual analysis. Statistical analysis may also be used in single-case designs, but its use is often a subject of debate.[16] A recent discussion of the statistical considerations in single-case designs, specifically related to the discipline of sports medicine, was undertaken by Bates[17] and Reboussin and Morgan.[18] Similarly, interested readers may find a more comprehensive review of the topic in Kazdin[14] and Kratochwill and Levin.[16]

Data are often collected in phases, ie, baseline and intervention. The effect of the intervention is clear when systematic changes in behavior occur during each phase in which the intervention is being withdrawn or presented.[14] Thus, the magnitude and rate of change is evaluated. The magnitude of change is assessed by a change in mean or change in level. The change in mean refers to a change in the arithmetic mean from one phase or condition to another (see Fig 1, graphs A and B). A change in level refers to a shift or discontinuity of performance from the end of one phase to the beginning of the next phase.[14] A consistent change in level following the implementation or withdrawal of an intervention indicates that the changes were a result of the treatment (Fig 1, graphs C and D). The rate of change is determined by examining changes in trend and latency of the change. A change in trend, or slope, details systematic increase or decrease over time (Fig 2, graphs E and F). Therefore, a change in trend is demonstrated by a change in the direction of data pattern movement.[19] Latency of the change refers to the period between the onset or termination of one condition and changes in performance (Fig 2, graphs G and H).[14] The sooner that changes in performance follow an intervention, the more confident we can be of the treatment effect. A researcher/clinician can be confident that a treatment is effective when there are changes in mean, level, trend, and latency of change following the intervention.

METHODS

Participants

We measured three boarding school male subjects on their ability to balance. All subjects had signed a consent-to-participate form or had parental permission prior to testing. The three subjects were high-school-letter winners, had previously sustained first-degree lateral ankle sprains, had no occurrence of an injury to either lower extremity within the

Table 1. Descriptive Values (Means and Standard Deviations) for the Three Subjects

Subject	Age (y)	Weight (kg)	Height (cm)	Injured Extremity
S1	19	79.38	190.5	Left
S2	18	79.38	187.9	Right
S3	16	77.11	180.3	Right
Mean (SD)	17.6 (1.24)	78.6 (1.07)	186.2 (4.3)	

3-month testing period, and were not participating in any other lower extremity-strengthening program during the testing period. Descriptive information for the three subjects is presented in Table 1.

We selected these subjects because they were good candidates for a preventive strength and proprioception training program as a result of prior and recurrent inversion ankle sprains. All three subjects reported suffering what could be determined (from past history) to be first-degree inversion ankle sprains. Subjective information supplied by the subjects revealed that past inversion ankle sprains did not require the use of ambulatory aids, and dysfunction following injury did not exceed 1 week. Objective evaluation of each subject with the anterior drawer and talar tilt tests revealed no obvious mechanical laxity when compared with the contralateral extremity.

Setting

Subjects were tested in an office adjacent to the athletic training room. The testing area was partially isolated from distractions, but occasionally another athlete passed through the area. Prior to any baseline testing, subjects reported to the athletic training room and were introduced to the testing procedure and training apparatus.

Dependent Measure

We tested dynamic balance three times a week using an SPBB. The SPBB was a 16½ by 16½-inch wooden board with a 3½-inch axis of rotation (Fig 3). The balance board could contact the floor in one of two planes (forward/backward or right/left). Each subject was tested for two double-leg conditions (forward/backward, right/left) and one single-leg condition (forward/backward) for each extremity (Fig 3). The dependent variable was the number of times that the balance board made contact with the floor. A "touch" was recorded when the SPBB came in contact with the floor as evidenced either visually or audibly. At each testing session the observer counted and recorded the scores for each subject.

Agreement

We conducted observer agreement checks on 20% of the observation sessions for subjects 2 and 3 and calculated agreements by a method similar to the point-by-point agreement procedure.[14] Following each testing condition in which observer agreement was scored, observer agreement was determined from the total number of times that the SPBB touched in a particular direction. For example, if observer 1 determined that the board touched 12 times in the forward position and observer 2 determined that the board touched 11 times in the forward position, eleven was used as the score for agreement and one was used as the score for disagreement. Observer agreement was conducted for baseline and intervention phases. The mean agreements were 0.91 during baseline and 0.92 during the intervention phase, indicating that two independent scorers obtained highly similar scores.

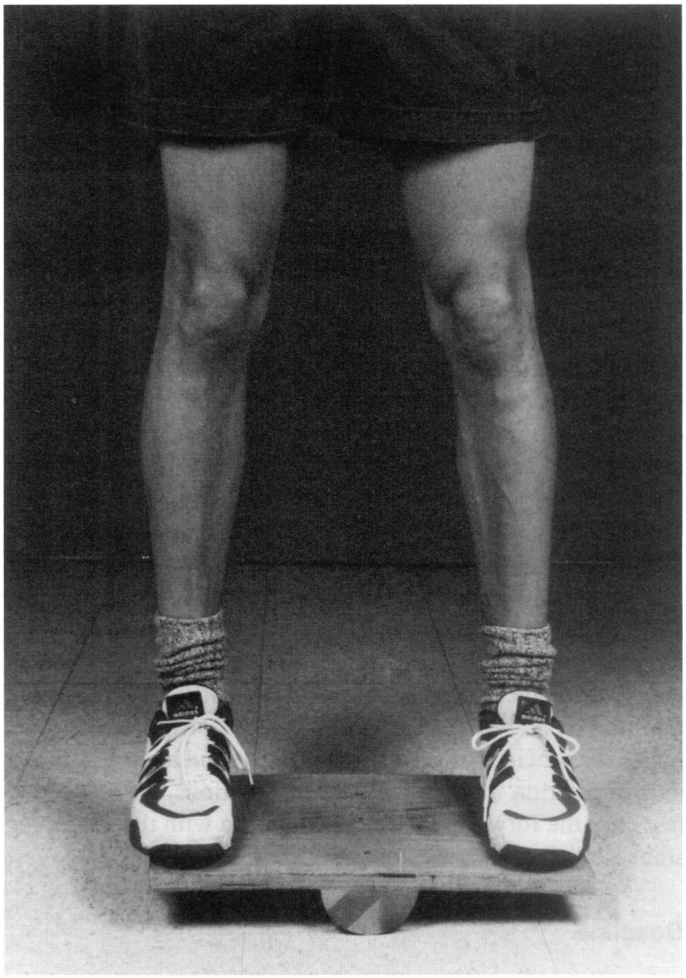

Fig 3. The single-plane balance board (SPBB), double-leg testing condition.

Experimental Procedure and Design

The primary investigator performed all observations, except for the sessions when interobserver agreement was scored. The testing lasted approximately 5 minutes, and the training session lasted 10 minutes per session for three sessions per week. We observed the subjects under baseline and intervention conditions. The change from baseline to intervention phases was made according to time-lagged procedures required by a multiple baseline design. A multiple baseline design shows the effects of a treatment by revealing that a subject's performance during baseline differs from performance during treatment and that those differences are not simply the result of time passing. The intervention phase was initiated with 1-week time lags. For example, subject 1 (S1) began the intervention phase after 1 week of baseline testing, subject 2 (S2) began the intervention phase after 2 weeks of baseline testing, and subject 3 (S3) began the intervention phase after 3 weeks of baseline testing. The interventions were staggered in this way so that subjects could begin the strength and proprioception training session as soon as possible. In order to assess the effectiveness of the training program, we wanted the intervention to last minimally 4 to 6 weeks. As a result, we could not sustain longer baselines because the subjects would not be on campus to test.

During each 40-second testing procedure, we asked the subjects to focus on an "X" marked on a wall directly in front of them while they tried to maintain their balance on the board and to prevent the edge of the board from touching the ground.

Subjects stood with their knees slightly flexed (5–15°) and their arms held at their sides. In the single-leg testing condition the nonweightbearing extremity was not allowed to touch the supporting leg. We began recording when each subject was properly positioned on the board and indicated he was ready. On each occasion, subjects were tested for a total of four tests, all with the eyes open. Double-leg stance was tested in the forward/backward and right/left position, and single-leg stance was tested in the forward/backward position only. The right/left condition was not tested in single-leg stance because it was shown during pilot testing that the task was too difficult to perform. Rather than increase the width of the axis of rotation and have a different axis of rotation for different testing positions, we decided to test only the forward/backward condition with the single-leg stance condition.

Baseline

Baseline data were collected three times a week, and the testing period lasted approximately 5 minutes. Baseline conditions lasted for three testing sessions for S1, seven testing sessions for S2, and fifteen testing sessions for S3.

Strength Training

The strength and proprioception training program was performed three times a week for 6 weeks and was described previously. Data were collected under similar conditions for all subjects. At the conclusion of the study, S1 had received the treatment conditions for 20 sessions (6.7 weeks), S2 had received the treatment conditions for 15 sessions (5.2 weeks), and S3 had received the treatment conditions for 16 sessions (5.5 weeks).

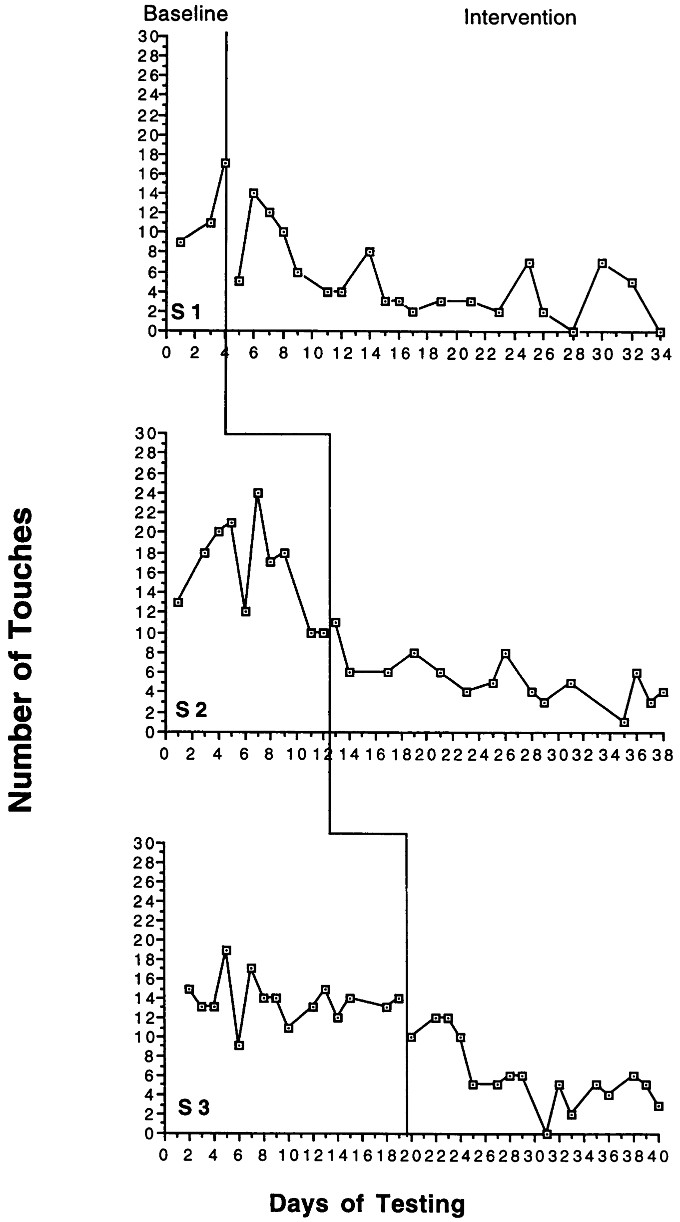

Fig 5. Values for all subjects for the double-leg forward/backward testing condition.

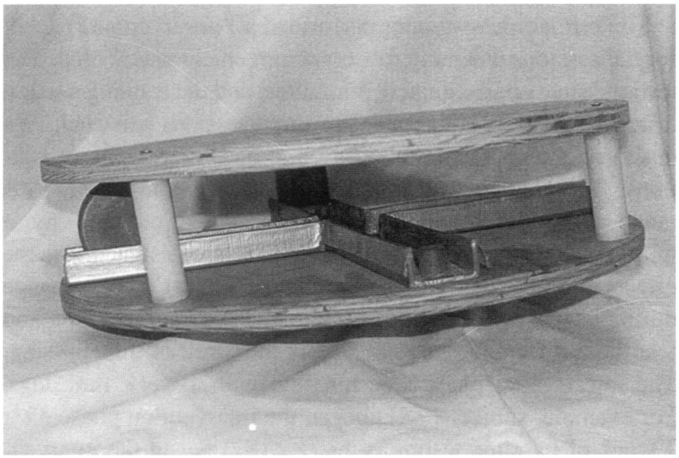

Fig 4. The kinesthetic ankle board (KAB).

The strength program consisted of a manual muscle resistance program for both extremities. The resistance for the isotonic contractions was performed by the primary investigator and consisted of manually resisting the following lower extremity movements: ankle plantar flexion, dorsiflexion, inversion, and eversion. The subject was supine for all strength movements except for the plantar flexion movement. In this instance the subject was prone. The primary investigator provided a constant resistance in all of the four directions. The subject was instructed to push as hard as he could for each repetition. Each repetition lasted approximately 3 seconds. The primary investigator counted out loud to maintain a consistent 3-second duration for each repetition. Subjects performed 3 sets of 10 repetitions for each strength movement. Following each strength training session, subjects then performed exercises targeted to improve proprioception.

Proprioception Training

Proprioception training consisted of performing 3 sets of 25 repetitions (with a single-leg stance) on the kinesthetic ankle board (KAB) (patent pending), in both clockwise and counterclockwise directions (Fig 4). Proprioception training was performed bilaterally.

The KAB has two .45-kg (1-lb) cylinders that are contained on a track shaped like a "+" on the underside of the platform. The cylinders are free to roll in this track as the KAB is moved in varying directions. The purpose of the free-moving cylinders is to attempt to increase proprioceptive feedback to the mechanoreceptors and joint receptors in the ankle. To our knowledge, this is the first time that this training apparatus has been used.

Subjects were seated in a chair and were instructed to keep their knees at a 90° angle while maintaining contact with the top of the KAB with their respective extremities. Subjects were instructed to keep the periphery of the board in contact with the floor as they moved the board clockwise and counterclockwise. Proprioception training with a circular board is commonly used to attempt to increase range of motion and proprioception following injury to the lower extremity.

To evaluate whether the treatment resulted in a change of performance we applied the principles of visual inspection discussed previously. We looked for changes in the mean performance across phases, changes in the level of performance (shift at the point that the phase is changed), changes in trend (differences in the direction and the rate of change across phases), and latency of change (rapidity of change at the point that the intervention is introduced or withdrawn) to determine whether a reliable effect had occurred.[14]

Table 2. Number of Touches for Each Subject for the Baseline and Intervention Phases for All Testing Conditions (Means, Standard Deviations)

Subject (Test Condition)	Baseline Mean (SD)	Intervention Mean (SD)
S1		
Double-leg forward/backward	12.3 (3.3)	5.7 (3.6)
Double-leg right/left	25.6 (2.6)	10.7 (5.0)
Right leg forward/backward	12.3 (7.5)	3.4 (4.5)
Left leg forward/backward	13.6 (3.8)	2.2 (2.4)
S2		
Double-leg forward/backward	17.8 (3.9)	8.4 (3.9)
Double-leg right/left	15.8 (3.5)	9.6 (4.1)
Right leg forward/backward	19.7 (2.6)	7.6 (4.0)
Left leg forward/backward	13.8 (4.8)	7.2 (2.7)
S3		
Double-leg forward/backward	13.7 (2.2)	9.8 (2.5)
Double-leg right/left	18.7 (2.8)	12.0 (1.2)
Right leg forward/backward	16.7 (4.2)	8.6 (2.4)
Left leg forward/backward	15.4 (4.8)	6.6 (1.7)

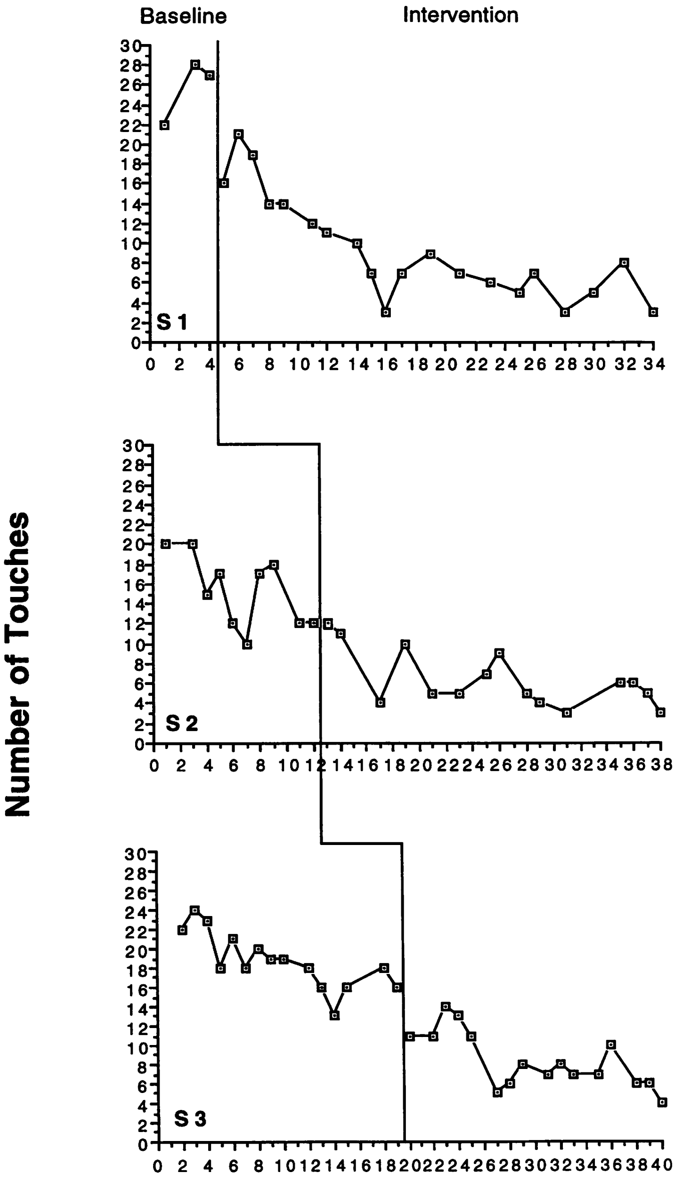

Fig 6. Values for all subjects for the double-leg right/left testing condition.

RESULTS

Double-Leg Forward/Backward Condition

There was a clear change in means from the baseline phase to the intervention phase for all three subjects (Table 2). There was a change in level and latency of change for subjects S1 and S3, but not for S2. There was a change in slope for S1 and S2 and appears to be a change in slope for S3. Thus the change in the dependent measure from baseline to the intervention phase can be attributed to the strength and proprioception training program for all three subjects for this condition (Fig 5).

Double-Leg Right/Left Condition

There was a clear change in the means from the baseline phase to the intervention phase for all three subjects (Table 2). There was a change in level and latency for subjects S1

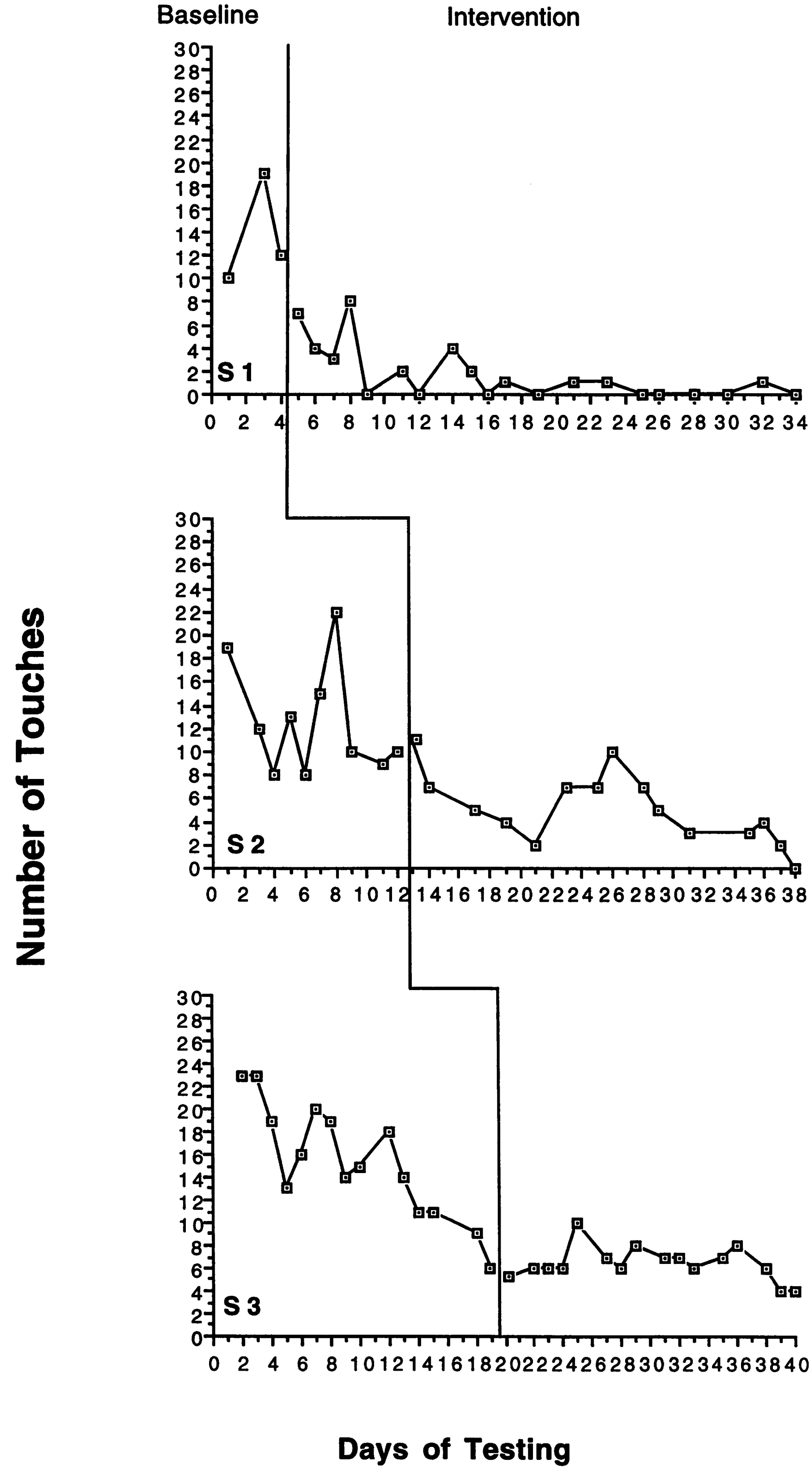

Fig 7. Values for all subjects for the right-leg forward/backward testing condition.

and S3, but not for subject S2. There appeared to be a change in slope for subject S1, but not for subjects S2 and S3. It appeared that the intervention was effective in improving the subjects' ability to balance on an SPBB for this condition (Fig 6).

Right-Leg Forward/Backward Condition

There was a clear change in the mean scores from the baseline phase to the intervention phase for all three subjects (Table 2). There was a change in level and slope only for S1.

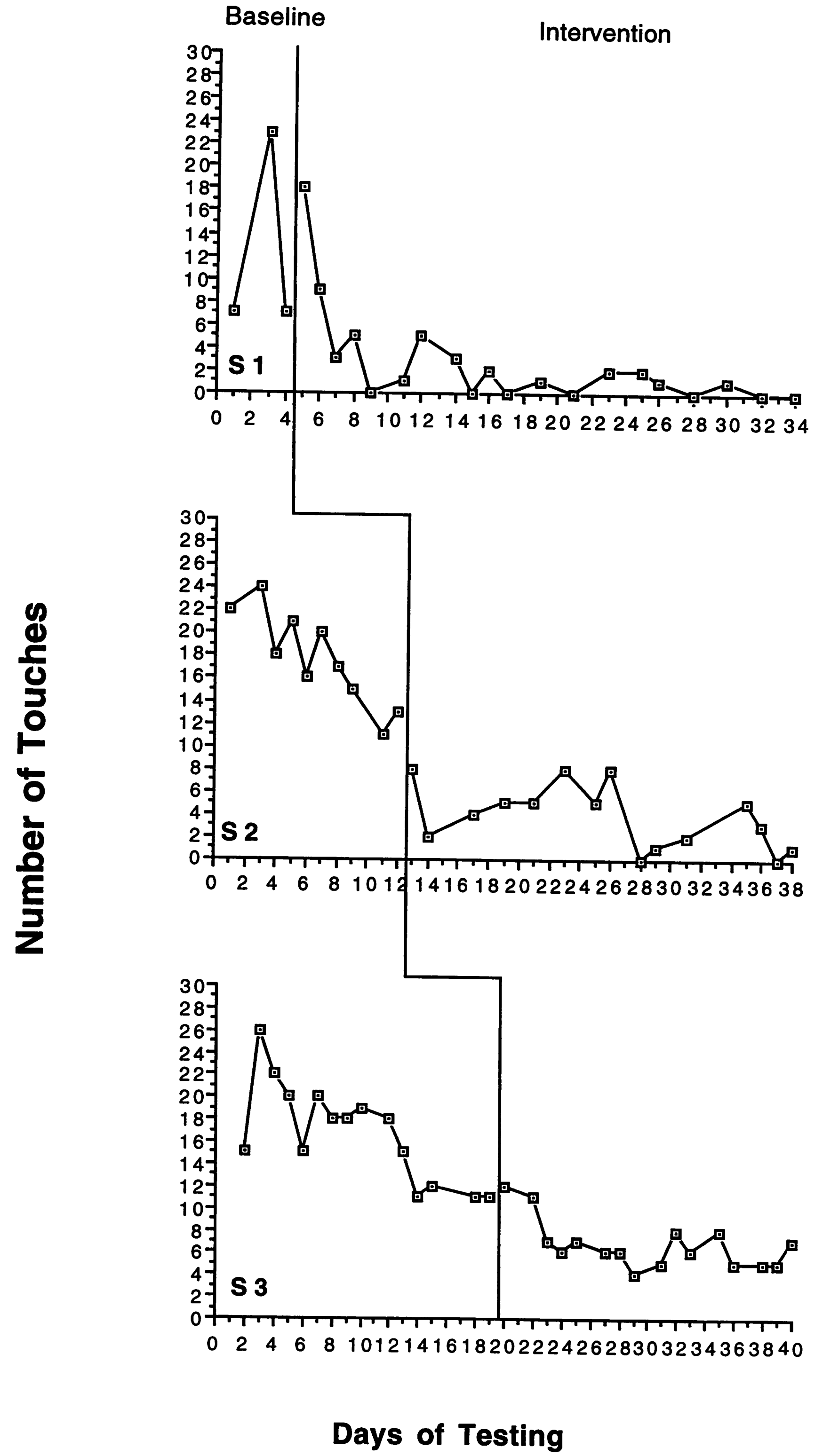

Fig 8. Values for all subjects for the left-leg forward/backward testing condition.

There was no change in latency for all three subjects. There was not a clear change in all criteria from baseline to intervention phase for the right-leg forward/backward condition. However, the clear change in mean score indicates that the treatment did have an effect on the improvement of all subjects' ability to balance dynamically even in the absence of other supporting criteria (Fig 7).

Left-Leg Forward/Backward Condition

There was a clear change in the mean scores from the baseline phase to the intervention phase for all three subjects (Table 2). There was a clear change in level, latency, and slope for S1 and S2, but not for S3. Based on these criteria, it can also be determined that there was an improvement in the subjects' ability to balance on an SPBB following the treatment phase (Fig 8).

DISCUSSION

Measurement of balance has numerous potential applications in athletic training, such as determining the effects of injury, surgery, and external devices such as tape and braces on balance. Following injury, assessing deficiencies of balance is often accomplished using static tests of balance. The purpose of our study was to assess a dynamic test of balance and to determine if improvements were possible following a 6-week strength and proprioception training program. Our preliminary results suggest that a manual resistance strength and proprioception training program can improve the ability to balance for dynamic testing conditions.

Although the intervention did not produce obvious improvements in balance for all evaluation criteria for all testing conditions, it is apparent that the strength and proprioception training program has positively influenced all three subjects' ability to balance dynamically on an SPBB. The change in mean scores from baseline to intervention phase is evident for all testing conditions.

However, the changes in slope and level were not as apparent for all testing conditions, especially the single-leg conditions. It is apparent from the data that there is a greater learning curve for the single-leg conditions. We feel that this can be explained because of the increased difficulty in performing these tests. The transition from baseline to intervention is commonly determined when the baseline behaviors stabilize so that subsequent data points can be predicted. One limitation of our study is that we did not have this luxury. As is often the case in the clinical setting, we wanted to start the strength and proprioception intervention with our subjects as quickly as possible. Time constraints necessitated starting the intervention phase so that each subject would have an equal and adequate interval of training before he had to leave campus for summer vacation.

Changes in mean, level, latency, and slope assure that an intervention is successful. A change in mean was evident for all conditions. However, a change in the other parameters was not as evident, especially when examining the injured extremity. For example, S1, who had injured his left ankle, demonstrated a change in all measures for the left-leg forward/backward conditions. Thus, the affected extremity was influenced in a positive manner via the treatments. The improvement for S2 and S3 (right ankle sprain) in the right-leg forward/backward conditions was not as clear when examining changes in level, latency, and slope. One explanation for this difference is that S1 received the treatment condition for a longer period of time. Further study is needed to examine objectively treatment parameters such as these that are commonly used in the clinical setting.

The integration of strength and proprioception training exercises is commonly employed following injury to the lower extremity. Recently, Leanderson et al[6] examined a group of ballet dancers and reported that proprioception can still be affected 1 year after injury following a rehabilitation program and subsequent return to competition. The effects of proprioception training have been evaluated using either static[4,10] or dynamic tests of balance on computer-interfaced force platforms.[5,6,11–13] Future research is needed to validate the use of these rehabilitation procedures and devices, with consideration for differing degrees of dysfunction. We recommend further examination of the effects of different strength and proprioception programs incorporating inexpensive devices such as the KAB and SPBB with other established computerized methods of measurement.

RECOMMENDATIONS

The maintenance of postural stability involves the integration of multiple physical components. As athletic trainers, we are interested in examining the relationships of these physical components for injured and uninjured athletes. The standardization of treatment protocols that are commonly used in athletic training offers an excellent environment to document the individual variability that is involved while an athlete is injured. With attention to detail, we propose that the use of single-case research designs be considered more frequently in the athletic training profession.

CONCLUSIONS

The results of this study indicate that a six-week manual resistance and proprioception training program improved the performance of three subjects for dynamic tests of balance. Our findings would support the continued rationale for recommending strength and proprioception exercises for individuals who have prior histories of first-degree lateral ankle sprains.[6]

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REFERENCES

1. Freeman MR, Dean M, Hanham I. The etiology and prevention of functional instabilities of the foot. *J Bone Joint Surg Br.* 1965;47:678–685.
2. Gauffin H, Tropp H, Odenrick P. Effect of ankle disk training on postural control in patients with functional instability of the ankle joint. *Int J Sports Med.* 1988;9:141–144.
3. Irrgang JJ, Whitney SL, Cox ED. Balance and proprioceptive training for rehabilitation of the lower extremity. *J Sport Rehabil.* 1994;3:68–83.
4. Balogun JA, Adesinasi CO, Marzouk DK. The effects of a wobble board exercise training program on static balance performance and strength of lower extremity muscles. *Phys Ther Can.* 1992;44:23–30.
5. Hoffman M, Payne VG. The effects of proprioceptive ankle disk training on healthy subjects. *J Orthop Sports Phys Ther.* 1995;21:90–93.
6. Leanderson J, Eriksson E, Nilsson C, Wykman A. Proprioception in classical ballet dancers: a prospective study of the influence of an ankle sprain on proprioception in the ankle joint. *Am J Sports Med.* 1996;24:370–374.
7. Mattacola CG, Perrin DH, Kaminski TW, Szczerba JE. Effects of a five week balance training protocol on postural sway and lower extremity strength. *J Athl Train.* 1995;30:S-33. Abstract.
8. Rowinski MJ. Afferent neurobiology of the joint. In: Gould JA, ed.

Orthopaedic and Sports Physical Therapy. St. Louis, MO: CV Mosby Company; 1990:49–63.

9. Byl NN, Sinnott PL. Variations in balance and body sway in middle-aged adults. *Spine*. 1991;16:325–330.
10. Friden T, Zatterstrom R, Lindstrand A, Moritz U. A stabilometric technique for evaluation of lower limb instabilities. *Am J Sports Med.* 1989;17:118–122.
11. Harrison EL, Duenkel N, Dunlop R, Russell G. Evaluation of single-leg standing following anterior cruciate ligament surgery and rehabilitation. *Phys Ther.* 1994;74:245–252.
12. Lebsack DA, Perrin DH, Hartman ML, Gieck JH, Weltman A. The relationship between muscle and balance performance as a function of age. *Isokinet Exerc Sci.* 1996;6:125–132.
13. Mattacola CG, Lebsack DA, Perrin DH. Intertester reliability of assessing postural sway using the Chattecx balance system. *J Athl Train.* 1995;30:237–242.
14. Kazdin AE. *Single-Case Research Designs*. 2nd ed. New York: Oxford; 1982:103.
15. Gonnella C. Single-subject experimental paradigm as a clinical decision tool. *Phys Ther.* 1989;69:601–609.
16. Kratochwill TR, Levin JR. *Single-case research design and analysis.* Hillsdale: Lawrence Erlbaum Associates; 1992:15.
17. Bates BT. Single-subject methodology: an alternative approach. *Med Sci Sports Exerc.* 1996;28:631–638.
18. Reboussin DM, Morgan TM. Statistical considerations in the use and analysis of single-subject designs. *Med Sci Sports Exerc.* 1996;28:639–644.
19. Wolery M, Harris SR. Interpreting results of single-subject research designs. *Phys Ther.* 1982;62:445–452.