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Effects of a 4-Week Exercise Program on Balance Using Elastic Tubing as a Perturbation Force for Individuals With a History of Ankle Sprains

- **STUDY DESIGN:** Randomized controlled trial with pretraining, posttraining, and follow-up repeated measures.
- **OBJECTIVE:** To determine the effectiveness of a 4-week elastic resistance exercise program on balance in subjects with and without a history of sprained ankles.
- **BACKGROUND:** Several researchers have suggested that improving balance may help alleviate the symptoms of functional ankle instability and reduce the rate of recurrent ankle sprains.
- **METHODS AND MEASURES:** Forty subjects (20 males, 20 females; 20 subjects with chronic ankle instability [CAI], 20 healthy) participated in the study. Ten subjects (5 males, 5 females) from each CAI and healthy group were randomly assigned to either the exercise or control group, resulting in a total of 4 groups. Total travel distance of the center of pressure, monitored using a force platform, was measured before training, after 4 weeks of training, and at a 4-week follow-up.
- **RESULTS:** There were no interactions between gender, ankle sprain history, or training groups. Balance significantly improved in subjects with and without a history of ankle sprains following 4 weeks of elastic resistance exercises. Mean improvement in balance for the exercise group following training, reflected through a decrease in total travel distance, was –11.1 cm (95% confidence interval: –14.0 to –8.2 cm). These improvements in balance were retained 4 weeks after training.
- **CONCLUSIONS:** Balance was improved after 4 weeks of elastic resistance exercise in subjects with and without a history of lateral ankle sprains. Balance improvements persisted 4 weeks following the treatment cessation.
- **LEVEL OF EVIDENCE:** Therapy, level 2b.

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- **KEY WORDS:** *ankle, chronic ankle instability, sprain, stabilometry*

Lateral ankle sprains are among the most common injuries incurred while performing both daily living and sport activities.[3,8,15,38] The rate of recurrence for lateral ankle sprains has been reported to be as high as 70%.[2,35] Individuals who have repeatedly sprained their ankle often report persistent symptoms of weakness, a feeling of "giving way," and pain during activity. This combination of persistent symptoms and repetitive lateral ankle sprains has been termed chronic ankle instability (CAI).[19,26,27,30]

Depending upon the severity of the injury to the ankle, a sprain may cause both pathologic laxity[21] and impaired sensorimotor control about the ankle.[36,39] Increased ankle joint laxity and sensorimotor deficits from a single or multiple ankle sprains have been shown to be related to impaired balance.[28] While it is difficult to directly prove that an ankle sprain causes impaired balance, there is indirect evidence that balance is impaired following an ankle sprain and impairments in balance can be improved within 4 weeks using rehabilitative exercises.[20]

Prospective studies have shown that ankle injury prevention exercises are effective in reducing the incidence of ankle injuries.[2,53] Verhagen[53] reported a significant reduction in the ankle sprain risk for volleyball players with a history of ankle sprains when balance board training was used as a normal part of the daily warm-up. Bahr[2] observed that an ankle injury prevention program consisting of land technique and balance board training resulted in a reduction of the incidence of ankle injuries for players with recurrent sprains.

Following an ankle sprain, a relatively high percentage of individuals develop chronically unstable ankles,[1,19,26,27] and these individuals report a feeling of giving way when performing athletics and

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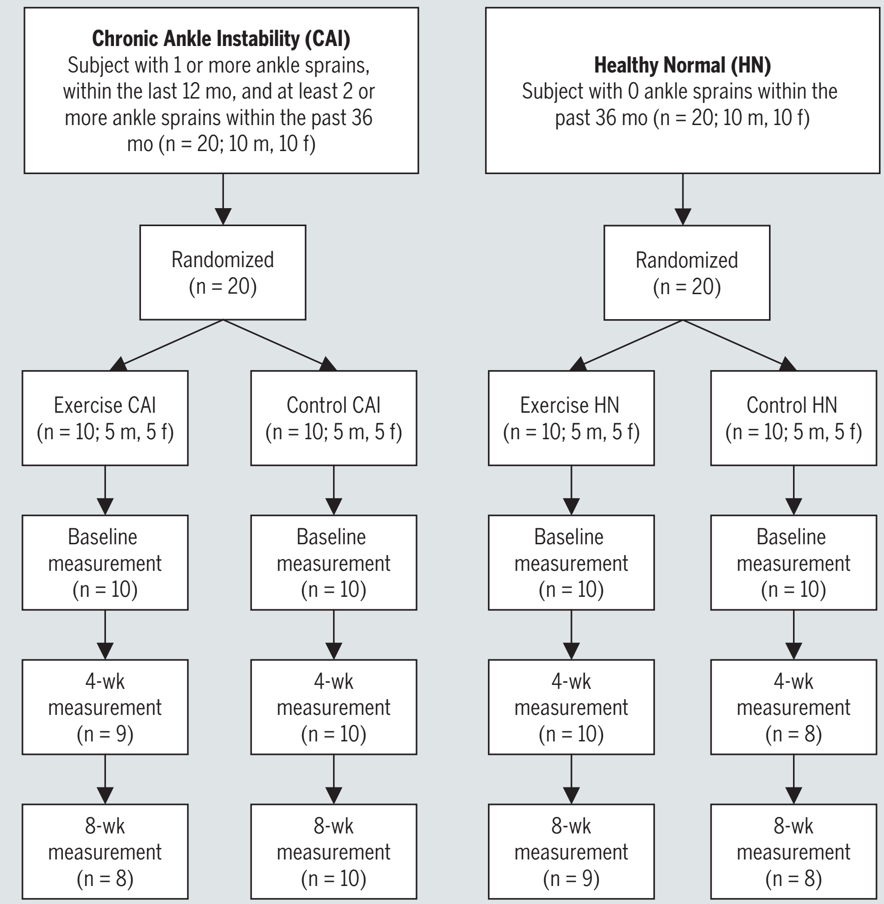

FIGURE 1. Flow-diagram of subjects throughout the course of the study. Abbreviations: f, females; m, males.

daily activities. Balance deficits have been frequently reported in individuals with chronically unstable ankles.[9,11,25,40,49] Therapists typically use a combination of strengthening and coordination exercises, with an ankle disk or wobble board, to rehabilitate the injured ankle joint.[4,13,14,18,33,46,50,51,54] These exercises have been recommended by numerous authors[13,14,50,51,53,54] to improve balance[4,14,24,51] and to reduce the incidence of ankle sprains.[17,50,53,54] For example, Gauffin et al[16] observed that 8 weeks of ankle disk training resulted in improved bilateral postural control in soccer players with a history of ankle sprains. More recently, Lee and Lin[30] demonstrated that a 12-week biomechanical ankle platform system (BAPS) training program significantly improved postural stability in subjects with functional ankle instability. When not constrained by time, a therapist may utilize a variety of rehabilitation exercises,[12] such as an ankle disk, weight training, elastic resistance exercises, and foam exercises to rehabilitate the ankle joint. However, usually both the patient and the therapist are limited in terms of time available for rehabilitation exercises.

Elastic tubing and elastic bands are often used in therapeutic exercise programs.[47,48] There are many inherent advantages of elastic resistance exercises: ease of use, low cost, they are highly versatile and finally they impose a weight-bearing overload on the joint to be rehabilitated. Physical therapists often use elastic tubing exercise in conjunction with other rehabilitation exercises to promote ankle strength and balance in patients with recurrent ankle sprains. When utilizing elastic resistance exercise to rehabilitate a chronically unstable ankle, the unaffected ankle is attached to the elastic tubing and the affected ankle experiences a weight-bearing overload to resist against the perturbation force. To maintain balance in response to the balance-disrupting force imposed by elastic tubing, the weight-bearing ankle must actively resist in the opposite direction against the imposed perturbation. In this study we sought to quantify the effect of this postural challenge imposed by the elastic resistance exercise on balance in individuals with and without a history of ankle sprains.

The purpose of this study was to determine the effect of a 4-week training program using 4 elastic tubing exercises consisting of front pulls, back pulls, crossovers, and reverse crossovers on balance in subjects with and without a history of ankle sprains.

METHODS

Design

The design of this study incorporates 2 treatment types and ankle sprain history, with repeated measures (**FIGURE 1**). The independent variables were treatment type (exercise or control) and ankle sprain history (CAI or healthy normal). The dependent variable was standing balance as measured by the total travel distance (TTD) of the center of pressure (CoP) using a force platform.

Subjects

A total of 40 subjects (20 males, 20 females) participated in this study. Twenty subjects (10 males, 10 females) who had experienced 1 or more ankle sprains within the past 12 months and at least 2 or more ankle sprains within the past 36 months, but at the time of the study had no visual swelling or pain, were recruited as subjects with CAI. Another 20 subjects (10 males, 10 females) who had not experienced an ankle sprain within the past 36 months were recruited as healthy normal subjects. Subjects were not explicitly blinded to the treatment (exercise, control) groups. All subjects had no history of fracture or major surgery in either lower extremity. Ten subjects (5 males, 5 females) from the CAI and 10 subjects (5 males, 5 females) from the healthy normal groups were randomly assigned to either resistance exercise or control groups, resulting in 4 groups of 10 subjects with equal male and female representation: exercise CAI, exercise healthy normal, control CAI, and control healthy normal. Subject characteristics, such as age, height, and body mass, are provided in **TABLE 1**. Prior to participation in this study, all subjects read and signed an informed consent document approved by The Brigham Young University Institutional Review Board for Human Subjects.

TABLE 1 Subject Characteristics*

	Exercise Chronic Ankle Instability (n =10)	Exercise Healthy Normal (n =10)	Control Chronic Ankle Instability (n =10)	Control Healthy Normal (n = 10)
Age (y)	20.1 ± 3.4	21.2 ± 4.3	21.9 ± 3.1	21.8 ± 4.5
Height (cm)	173.9 ± 11.9	169.7 ± 10.4	176.0 ± 7.2	171.7 ± 11.4
Body mass (kg)	67.0 ± 10.2	64.8 ± 11.2	74.3 ± 12.3	66.6 ± 17.3

* *Values presented as mean ± SD. Exercise groups completed 4 weeks of elastic resistance exercise training.*

FIGURE 2. Front pull exercise. The subject stood on the affected foot, flexing the unaffected lower extremity at the hip and knee, while pulling the tubing forward (A to B), then slowly returned to the starting position (B to A).

FIGURE 3. Back pull exercise. The subject stood on the affected foot, flexing the unaffected lower extremity at the hip and knee, while pulling the tubing backward (A to B), then slowly returned to the starting position (B to A).

Instrumentation

Subjects performed resistance exercise using the strongest elastic tubing (Functional PT Products, Heber City, UT), with an internal diameter of 7 mm, external diameter of 16 mm, a length of 185 cm, and a padded foot strap on each end. Tension in the elastic tubing was monitored using a Chatillon Model CSD 200C Dynamometer (Itin Scale Co, Inc, Brooklyn, NY). A force plate (AMTI Inc, Newton, MA) was used to calculate CoP from ground reaction forces. The force data were sampled at 100 Hz for 20 seconds using a Gateway Solo 9100 interfaced to a Keithley-Metrabyte KP-CMCIA, 12-channel, 16-bit analog-to-digital converter (Keithley Instruments Inc, Cleveland, OH).

Exercise Protocol

Elastic tubing exercises for the exercise group consisted of 4 different exercises: front pull, back pull, crossover, and reverse crossover. Subjects assigned to the exercise group made 3 visits per week, every other day for 4 weeks, to perform the elastic tubing exercises. Each exercise consisted of 3 sets of 15 repetitions, with the chronically unstable ankle foot (exercise CAI group) or randomly assigned foot (exercise healthy normal group) on the ground and 1 end of the elastic tubing attached to the other foot. Subjects had a 30-second rest between each exercise and a 2-minute rest between sets. The tension of the elastic tubing for the exercises was a percentage of the subject's body mass: 16% (first week), 18% (second week), 20% (third week), and 22% (fourth week).

Description of the Exercises

The following procedures were used for each of the 4 elastic tubing exercises. Subjects with CAI used their unaffected foot to pull on the elastic tubing and they used the lower extremity with CAI to support their body weight. For the healthy normal subjects, 1 foot was randomly assigned to correspond to the side of the affected ankle of the subjects with CAI. Resistive exercise was performed by attaching one end of the elastic tubing to the unaffected foot at the level of the malleoli, while the other end was fixed to a stable attachment. The subject stepped away from the tubing attachment site, stretching the tubing to obtain the desired resistance. The length-tension relationship of the cord was measured and different cord lengths corresponding to the different tensions were marked on the floor. The subjects were instructed to stand at the marked position to ensure that the exercise was performed at the proper tension. The length-tension relationship of the cord was verified each day.

Front Pull The subject faced away from the fixed attachment of the elastic tubing so that the tubing pulled the subject backward. Each subject stood on the affected foot with the unaffected foot positioned behind the affected foot with the hip and knee extended (**FIGURE 2A**). While balancing on the affected foot, the subject flexed the unaffected hip and knee, pulling the tubing forward (**FIGURE 2B**). The subject then slowly returned to the starting position (**FIGURE 2A**).

Back Pull The subject faced toward the fixed attachment of the elastic tubing, so that the tubing pulled the subject forward. The subject stood on the affected foot, with the unaffected foot positioned ahead of the affected foot with the hip and knee flexed (**FIGURE 3A**). While balancing on the affected foot, the subject extended the uninjured lower extremity at the hip and knee, pulling the tubing backward (**FIGURE 3B**). The subject then slowly returned to the starting position (**FIGURE 3A**).

Crossover The subject stood perpendicular to the fixed attachment of the elastic tubing, so that the unaffected foot was closer to the fixed attachment, with the

FIGURE 4. Crossover exercise. The subject stood on both the affected and unaffected lower extremities, with hip and knees flexed. While balancing on the affected foot, the subject adducted the hip by crossing the unaffected foot in front of the affected foot (A to B), then slowly returned to the starting position (B to A).

FIGURE 5. Reverse crossover exercise. The subject stood on both the affected and unaffected lower extremities, with hip and knees flexed and the unaffected lower extremity adducted in front of the affected foot. While balancing on the affected foot, the subject abducted the hips until the feet were slightly wider apart than shoulder width (A to B), then slowly returned to the starting position (B to A).

feet slightly wider than shoulder width apart (**FIGURE 4A**). The subject stood on both the affected and unaffected lower extremities, with hip and knees flexed. While balancing on the affected foot, the subject adducted the hips by crossing the unaffected foot in front of the affected foot (**FIGURE 4B**). The subject then slowly returned to the starting position (**FIGURE 4A**).

Reverse Crossover The subject stood perpendicular to the fixed attachment of the elastic tubing. The subject's unaffected foot was closer to the fixed attachment with the hips adducted and lower extremities crossed so that the unaffected foot was in front of the affected foot (**FIGURE 5A**). The subject stood on both the affected and unaffected lower extremities with hips and knees flexed. While balancing on the affected foot, the subject abducted the hip until the feet were slightly wider apart than shoulder width (**FIGURE 5B**). The subject then slowly returned to the starting position (**FIGURE 5A**).

Evaluations

The subjects' height, body mass, age, gender, dominant foot, and history of ankle sprains were recorded. The dominant foot was denoted as the foot used to dropkick a tennis ball into a basket 5 m away. Each subject was required to wear the same low-top tennis shoes (Lozan; K-Swiss Inc, Westlake Village, CA) for testing. All subjects made 3 visits to the laboratory for testing: pretraining, posttraining (immediately following 4 weeks of treatment), and 4-week follow-up (4 weeks after treatment cessation). The evaluations were made within 4 days prior to the start of the first week of training, within 4 days of the end of the fourth week of training, and within 4 days of the eighth week. Forty subjects completed the baseline evaluation, 37 subjects completed the 4-week evaluation, and 35 subjects completed the 8-week evaluation (**FIGURE 1**). Testers were not blinded to the subjects' group assignment.

Balance Balance was measured on the AMTI force plate during single-limb standing. Subjects stood for 20 seconds on the affected foot, with the nonaffected extremity's hip flexed 30° and knee flexed 70°, and both arms at their sides (**FIGURE 6**). The subjects were asked to focus on a blue circle (10 cm in diameter) placed 3 m away at eye level. Healthy normal subjects stood on their randomly assigned foot used to support body mass during the exercises, and all other conditions were the same as for the symptomatic subjects. Three trials of balance were performed by each subject and recorded, with a 30-second rest between subsequent trials. The force data were sampled at 100 Hz for 20 seconds. The coordinates (x, y) of the CoP were determined from the force data. TTD in cm was then calculated by summing the displacement of the x and y components of the CoP as a function of time using the following equation:

$$TTD = \sum_{i=1}^{i=n-1} \sqrt{(x_{i+1} - x_i)^2 + (y_{i+1} - y_i)^2}$$

Reliability Analysis and Minimal Detectable Change

Nine subjects (not in the experiment) participated in a test-retest assessment of measurement reliability. TTD was measured on 2 separate days, and between-day reliability was determined using SPSS Version 16.0 to compute the intraclass correlation coefficient (ICC), using a 2-factor mixed-effects model and type consistency. The between-day ICC for TTD was 0.946, with a 95% confidence interval (CI) from 0.759 to 0.988. The standard error of measurement (SEM), or "typical error of measurement," was calculated by dividing the SD of the between-day differences by $\sqrt{2}$. The SEM was used to calculate the minimum detectable change (MDC) within 95% confidence limits (MDC_{95} = 2.77 × SEM). The mean ± SD between-day differences for TTD was 2.91 ± 2.66 cm. The SEM for TTD was 1.88 cm and the MDC_{95} was 5.22 cm.

FIGURE 6. Balance was measured on the force plate during single-limb standing. Subjects stood for 20 seconds on the foot with chronic ankle instability, focusing on a 10-cm-diameter circle placed 3 m away at eye level.

Sample Size Determination

G*Power Version 3.0 was used to determine sample size using a meaningful significant difference in TTD of 10.44 cm (2 × MDC_{95}), an SD of 5.32 cm, a 2-tailed t test and an alpha level of .05. To obtain an estimated power of 80%, 5 subjects per group were required.

Statistical Analysis

The 3 trial averages for TTD for each group were analyzed in SAS using a linear mixed model,[52] with an autoregressive lag 1 covariance structure and linear slopes, as implemented in SAS Proc Mixed[31] (SAS Institute Inc, Cary, NC), to determine intercepts and slopes for the dependent variable during the exercise and the follow-up phases of this study. The linear mixed model had 3 fixed factors: treatment (exercise, control), ankle sprain history (CAI, healthy normal), and gender (male, female), and 1 random factor (subjects). Linear mixed-model intercepts and slopes of different groups were compared for differences using t tests with an alpha of less than .01 as the critical level of significance.

RESULTS

Balance

The means, standard errors of the mean, and the results of the growth curve analysis for TTD by time (pretraining, posttraining, and 4-week follow-up) are shown in **TABLE 2**. Linear mixed models have been shown to be more powerful than a traditional analysis of variance (ANOVA) approaches for analysis of repeated-measures experiments.[52] Instead of comparing means across treatments and time points, and dealing with complex interpretation of the model interaction terms, linear mixed models tested for differences in initial values and in the slopes of each factor, allowing for a more straightforward interpretation of data.[52] Unlike traditional ANOVA methods, linear mixed models can effectively handle missing data points in repeated-measures designs, and, as a result, the data for the 5 subjects who dropped out (**FIGURE 1**) were retained.[31] In the present study, there were no 2-way or 3-way interactions between treatment, ankle sprain history, and gender for TTD. While not statistically significant, the healthy normal subjects demonstrated a trend toward better balance (mean difference, 9.2 cm; 95% confidence interval [CI]: –3.0 to 21.5 cm) prior to training (pretraining) when compared to the subjects with CAI. There was no difference in the pretest values for balance between the exercise and control groups (t = 0.99; P = .328), suggesting that the groups were similar at the start of the 4-week elastic resistance training program. Finally, on the initial test, female subjects had significantly (t = 2.81; P = .009) better balance than the male subjects.

The 4-week elastic resistance exercise program caused a significant improvement in balance for the exercise group when compared to the control group (t = –5.51; P<.001) and in the CAI group versus healthy normal group (t = –2.76; P<.01) (**TABLE 2**). Subjects with and without a history of ankle sprains in the exercise group improved balance, as measured by a decrease of the TTD of the CoP by 11.1 cm, with a 95% CI of –14.0 to –8.2 cm. This CI clearly excludes the MDC_{95} of 5.22 cm calculated based on reliability data, providing a high level of confidence that this change can be attributed to the training and not measurement error. Subjects in the nonexercise control group (with and without a history of ankle sprains) showed no change in bal-

TABLE 2 Total Travel Distance in cm Pretraining, Posttraining, and 4-Week Follow-up

	Mean	SE	t*	P Value
Pretraining				
Treatment			0.99	.328
Exercise	97.9	4.4		
Control	91.7	4.4		
Difference	6.2	6.2		
Ankle sprain history			1.49	.147
CAI	99.5	4.3		
Healthy normal	90.2	4.4		
Difference	9.3	6.2		
Gender			2.81	.009
Male	103.6	4.5		
Female	86.0	4.3		
Difference	17.6	6.2		
Posttraining (change over the first 4 wk)				
Treatment			–5.51	.001
Exercise	–11.1	1.5		
Control	0.5	1.5		
Difference	–11.6	2.1		
Ankle sprain history			–2.76	.010
CAI	–8.2	1.5		
Healthy normal	–2.4	1.5		
Difference	–5.8	2.1		
Gender			–1.11	.276
Male	–6.4	1.6		
Female	–4.1	1.4		
Difference	–2.3	2.1		
Change over the 4-wk follow-up				
Treatment			–0.07	.941
Exercise	–0.3	2.0		
Control	–0.1	2.0		
Difference	–0.2	2.8		
Ankle sprain history			0.55	.588
CAI	0.6	1.9		
Healthy Normal	–0.9	2.1		
Difference	1.5	2.8		
Gender			0.02	.984
Male	–0.1	2.2		
Female	–0.2	1.8		
Difference	0.1	2.8		

Abbreviations: CAI, chronic ankle instability; SE, standard error of the mean.
** t test for pretraining, posttraining, and 4-week follow-up tests compare differences between exercise and control, chronic ankle instability and healthy normals, males and females.*

ance, as illustrated by an average change of TTD of 0.5 cm, with a 95% CI of –2.4 to 3.5 cm. Individuals with a history of ankle sprains improved their balance, as measured by a decrease of the TTD of the CoP by 8.2 cm, with a 95% CI of –11.0 to –5.3 cm, whereas healthy normal subjects only decreased TTD by 2.4 cm (95% CI: –5.4 to 0.6).

On the 4-week follow-up test there were no differences in the change in balance (TTD) between the groups, indicating that the improvements in balance observed following training (posttest) for the subjects in the exercise group were retained (**TABLE 2**).

DISCUSSION

THE GOAL OF THIS STUDY WAS TO determine the effects of a 4-week elastic resistance exercise program on balance in individuals with and without a history of ankle sprains. Elastic resistance exercises are commonly used in rehabilitation because they enable the clinician to utilize a safe and effective weight-bearing progressive overload to rehabilitate the injured patient.[33] When using elastic resistance to rehabilitate an injured joint, the clinician can easily adjust the resistance in small increments to match the patient's progress by increasing or decreasing the stretch of the elastic tubing. In addition, subtle changes in support foot position can alter the direction and magnitude of the resistance joint torques required by the support limb to maintain balance. Elastic resistance exercises have been primarily used for shoulder,[23] knee,[5-7] and ankle joints[10] rehabilitation. Most ankle rehabilitation programs utilize a combination of strengthening exercises in conjunction with coordination exercises with an ankle disk or wobble board.[4,13,14,33,50,51,54] In this study we sought to quantify the rehabilitative training effect of 4 weeks of training, utilizing only elastic resistance exercise, on balance. We anticipated that the perturbation imposed by the elastic resistance exercise would elicit meaningful improvements in balance. The elastic resistance exercise program was equally effective in improving balance in subjects with and without a history of ankle sprains. Finally, these observed improvements in balance following elastic resistance exercise training were retained 4 weeks after training.

The 4 elastic resistance exercises utilized in this training program (front pull, back pull, crossover, and reverse crossover) impose a postural control challenge that ankle, knee, and hip joints of the support limb must effectively resist to maintain balance. Balance is the ability to maintain upright posture while keeping the center of gravity within the base of support.[29] To maintain balance in response to the balance disrupting force imposed by elastic tubing, the weight-bearing ankle must actively resist in the opposite direction against the imposed perturbation. Because the human body is not statically stable even during quiet double-limb stance, the central nervous system must constantly make adjustments to keep the center of mass over the base of support. Loram and Lakie[32] recently suggested that the central nervous system utilizes a "throw-and-catch" pattern to generate joint torques on opposite sides of the joint to maintain equilibrium while standing. In the present study, subjects were required to maintain balance while resisting against the balance disturbing force caused by the tension in the elastic tubing. It is possible that the perturbation caused by the elastic tubing imposes an accentuated neural training effect similar to the throw-and-catch pattern proposed by Loram and Lakie.[32] Future research on the putative training mechanism caused by elastic resistance exercise would require analyzing both joint kinetics and muscle activation during the elastic resistance exercise.

Tropp[49] suggested that coordination training should include activities that provoke ankle inversion and eversion to improve neuromuscular performance and to reduce ankle injury rates. In the present study, the balance perturbation provided by the elastic tubing exercises caused the weight-bearing ankle to resist forces causing inversion, eversion, dorsiflexion, and plantar flexion about the ankle joint. Clinical evidence has shown that balance training is effective in reducing the recurrence of ankle sprains.[25,53,54] The underlying neural mechanisms of clinical observations of improved balance are complex and difficult to directly verify. Hertel[19] suggested that balance or postural control training might impose a neural stimulus that causes the central nervous system to "retune" input and output processing of somatosensory information necessary to control balance.

Impaired balance has been frequently observed in individuals with a history of repetitive ankle sprains.[11,20] Individuals with poor balance have been shown to incur 6 to 7 times as many ankle sprains when compared to those with good balance.[34] Impaired balance observed in individuals with CAI may be due to sensorimotor deficits[41-44] in either movement detection, movement control, or both.[22] The results of the present study suggest that elastic resistance exercises can improve balance in subjects with a history of repetitive ankle sprains.

Individuals with a history of ankle sprains improved their balance significantly more than healthy normal individuals (**TABLE 2**). The CAI group improved by 8.2 cm, whereas the healthy normal group improved by 2.4 cm. The mean improvement of 8.2 cm for the CAI group includes subjects in the exercise and control groups. The small improvement observed in the CAI control group could be attributed to a short-term recovery effect that occurs with or without treatment.[1] Aiken et al[1] recently observed that following standard emergency care for grade I and II ankle sprains clinically, but not biomechanically, assessed measures of ankle impairment are resolved within 1 month. We initially hypothesized that there would be an interaction between time (pretraining, posttraining,

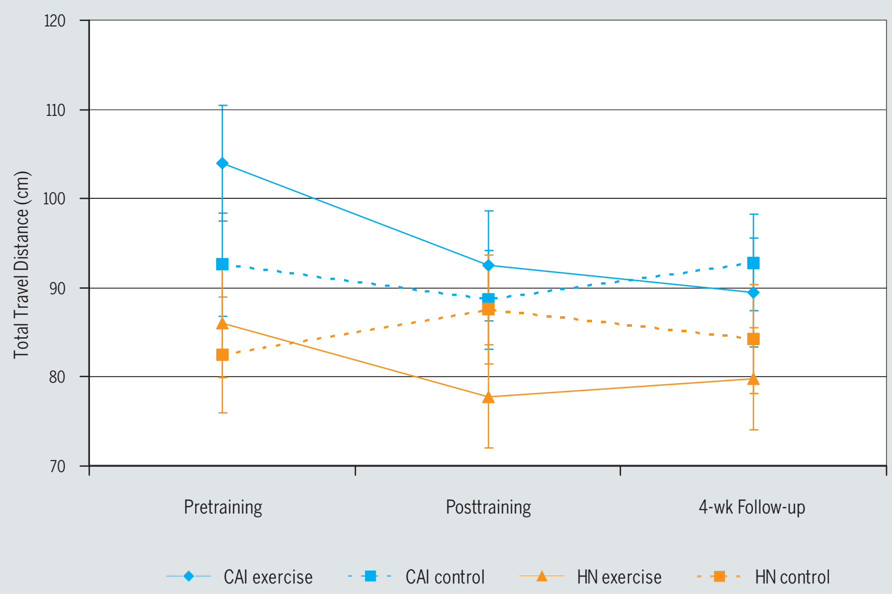

FIGURE 7. Mean ± SE for total travel distance by time (pretraining, posttraining, 4-week follow-up), ankle sprain history (chronic ankle instability, healthy normal), and treatment (exercise, control). The interaction between time, treatment, and ankle sprain history was not significant (P = .146). Abbreviations: CAI, chronic ankle instability; HN, healthy normal; SE, standard error of the mean.

4-week follow-up), ankle sprain history (CAI, healthy normal), and treatment (exercise, control). The interaction between time, ankle sprain history, and treatment, shown in **FIGURE 7**, was not significant (P = .146). Based upon our results, additional research is needed to ascertain if the improvement in balance for the CAI control group is the result of a short-term recovery or simply a learning effect from repeated balance testing.

Several other investigators have shown that ankle rehabilitation exercises can improve balance.[4,16,24] Freeman et al[14] may have been the first to demonstrate that balance training using a tilting balance platform improves balance in individuals with functionally unstable ankles. Rozzi et al[45] trained subjects with functionally unstable ankles for 4 weeks using the Biodex Stability System. Prior to training, subjects in the functionally unstable group had a 27% deficit in single-limb balance ability. Following training, the subjects with the functionally unstable ankle had single-limb balance scores that were almost identical to the posttraining scores of the healthy subjects. Furthermore, the subjects with the functionally unstable ankle also reported an improvement in perceived ankle joint functional stability, as measured by the Ankle Joint Functional Assessment Tool.[45] Eils and Rosenbaum[12] also reported a significant reduction in TTD of CoP following a 6-week multistation proprioceptive exercise program in patients with ankle instability. The exercise program utilized by Eils and Rosembaum included elastic Thera-Bands in conjunction with uneven walkways, inversion boards, and a variety of additional proprioceptive rehabilitation exercises.

There are very few ankle rehabilitation training studies that have used exclusively elastic resistance exercises.[33] In a study by Docherty et al[10] subjects with functionally unstable ankles showed an increase in dorsiflexion and inversion strength and an improvement in inversion and plantar flexion joint position sense following training.

While we have shown that balance training utilizing elastic tubing as a perturbation force can improve balance in individuals with and without a history of ankle sprains, we do not know the extent to which this improvement in balance might lead to a reduction in the recurrence of ankle sprains for individuals with chronically unstable ankles or the incidence of ankle sprains in individuals without a history of ankle sprains. In a recent review paper on postural control and ankle instability, McKeon and Hertel[37] suggested that balance and coordination training might be an effective intervention to reduce both the incidence and recurrence of ankle sprains. Based on clinical evidence, they recommended the use of balance and coordination training for individuals with a history of ankle sprains. It seems that randomized clinical controlled trials on the effects of elastic resistance training on the reduction of incidence and recurrence of ankle sprains are needed. Finally, in the present study, the lack of interaction between treatment (exercise, control) and ankle history (CAI, healthy normal) following training is somewhat unexpected and, therefore, we suggest future investigations should increase the intensity or duration of training to confirm this outcome.

CONCLUSION

Balance was improved in subjects with and without a history of multiple ankle sprains using a 4-week elastic tubing exercise program, in which resistance movements were performed in 4 directions (front pull, back pull, crossover, and reverse crossover), for 3 sets of 15 repetitions, 3 times per week. Improvements in balance following elastic resistance training were retained 4 weeks after cessation of training. We do not know if elastic resistance rehabilitation exercises will cause a reduction of functional instability and reduction in reoccurrence of ankle sprains.

KEY POINTS

FINDINGS: Balance was improved after 4 weeks of elastic resistance exercise in individuals with and without a history of lateral ankle sprains. In addition, balance improvements were retained 4 weeks following the cessation of treatment.

IMPLICATION: Elastic resistance exercises should be considered for use in both home and clinic based treatment. These exercises are simple to perform and impose a weight-bearing overload that is readily adjustable as the patient progresses.

CAUTION: We do not know if elastic resistance exercise rehabilitation will translate into a reduction of functional ankle instability and in reoccurrence of ankle sprains.

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