The Effect of a Balance Training Program on the Risk of Ankle Sprains in High School Athletes

Timothy A. McGuine,* PhD, ATC, and James S. Keene, MD
From the University of Wisconsin, Hospital and Clinics, Sports Medicine Center, Madison, Wisconsin

Background: Ankle sprains are the most common musculoskeletal injuries that occur in athletes, and they have a profound impact on health care costs and resources.

Hypothesis: A balance training program can reduce the risk of ankle sprains in high school athletes.

Study Design: Randomized controlled clinical trial; Level of evidence, 1.

Methods: Seven hundred and sixty-five high school soccer and basketball players (523 girls and 242 boys) were randomly assigned to either an intervention group (27 teams, 373 subjects) that participated in a balance training program or to a control group (28 teams, 392 subjects) that performed only standard conditioning exercises. On-site athletic trainers recorded athlete exposures and sprains.

Results: The rate of ankle sprains was significantly lower for subjects in the intervention group (6.1%, 1.13 of 1000 exposures vs 9.9%, 1.87 of 1000 exposures; $P = .04$). Athletes with a history of an ankle sprain had a 2-fold increased risk of sustaining a sprain (risk ratio, 2.14), whereas athletes who performed the intervention program decreased their risk of a sprain by one half (risk ratio, 0.56). The ankle sprain rate for athletes without previous sprains was 4.3% in the intervention group and 7.7% in the control group, but this difference was not significant ($P = .059$).

Conclusion: A balance training program will significantly reduce the risk of ankle sprains in high school soccer and basketball players.

Keywords: ankle sprain; prevention; soccer; basketball; high school

Ankle sprains are the most common musculoskeletal injury that occurs in athletes, and several studies have noted that sports that require sudden stops and cutting movements, such as basketball and soccer, cause the highest percentage of these injuries.† Ankle sprains not only result in numerous visits to emergency care facilities[13] and significant time loss from sports participation,[2,25] but they can also cause long-term disability[2,6,8] and have a major impact on health care costs and resources[1,2] (US Consumers Product Safety Commission, written communication, March 2005). The financial impact of these injuries on society is borne out by the fact that in the United States alone, 4.8 million grade school and 1.7 million high school athletes participate in supervised soccer and basketball programs[17] and, on average, 15% (1 million) of these athletes sustain ankle sprains each year.[12,18,21] The costs associated with treating this number of sprains are staggering. In 2003 alone, the US Consumer Products Safety Commission estimated that the direct medical cost of treating ankle sprains in high school soccer and basketball players (ages 15-18 years) was $70 million, and the indirect costs were $1.1 billion.[26]

Despite the enormous health care costs associated with this injury, critical reviews have identified only a limited number of studies that have the appropriate methodology to examine the effectiveness of ankle sprain prevention measures in general[3,9,16,24] and 2 studies that examine the efficacy of proprioceptive training in particular.[4,27]

The most rigorous studies have documented that ankle disk training will significantly reduce the risk of ankle sprains in adult athletes with a history of an ankle sprain.[4,11,22,23,25,26] However, the efficacy of a balance training program as a primary intervention for the prevention of sprains in athletes with healthy ankles remains to be determined. In addition, the studies published to date do not indicate whether proprioceptive training programs reduce the severity of initial or subsequent ankle sprains

*Address correspondence to Timothy A. McGuine, PhD, ATC, 621 Science Drive, Madison, WI 53711 (e-mail: ta.mcguine@hosp.wisc.edu).

†References 1, 3, 7, 9, 12, 14, 17, 18, 21, 30.

Presented at the 31st annual meeting of the AOSSM, Keystone, Colorado, July 2005.

No potential conflict of interest declared.

The American Journal of Sports Medicine, Vol. 34, No. 7
DOI: 10.1177/0363546505284191

or increase the number of exposures before an ankle sprain occurs.

The primary objective of this randomized intervention trial was to determine if a program of balance training, implemented in the preseason and maintained throughout the season, would reduce the risk of ankle sprains in male and female high school athletes. This study also sought to determine whether (1) the effect of the intervention was the same for athletes with or without a history of an ankle sprain; (2) the rate of ankle sprain was affected by independent variables such as gender, sport, leg dominance, use of ankle supports, and ankle laxity; and (3) balance training reduced the severity of ankle sprains.

METHODS

Sample size

Previous authors have reported an incidence of acute ankle sprains in athletes that ranged from 11% to 20%.[3,7,21,24,26] On the basis of these data, we projected a sprain rate for this study of 15% in the control group and 7.5% in the intervention group. Using these rates, we calculated the sample size to determine statistical significance by using cluster randomization as well as a 2-tailed test with $\alpha = .05$ and $1\text{-}\beta = .80$. The estimated sample size for this study thus obtained was 680 (340 in both the intervention and control groups).

Randomization

Randomization into intervention and controls was performed using groups of two based on a schedule provided by the statistician (Figure 1). In this type of randomization, each member of an individual team was assigned to the same intervention or control group. The group randomization procedure we used is not considered optimum in randomized clinical trials. However, this procedure is widely used and accepted in sports injury prevention trials as a way to limit contamination between intervention and control groups.[4,27,28] In addition, each school district had a similar policy that stated any intervention must be offered to all members of a class or team as a group rather than as individuals.

Subjects

Seven hundred and sixty-five basketball and soccer players (523 girls and 242 boys) from 12 area high schools that utilized certified athletic trainers (ATCs) from our Sports Medicine Clinic agreed to participate in the study. Subjects were recruited by giving study materials to potential subjects, posting flyers in the schools, sending letters to school administrators, meeting with coaches, and talking with parents at preseason team meetings.

To be included in the study, subjects had to be on the interscholastic basketball or soccer team roster compiled by their head coach. In addition, each subject had to be able to practice or play the first day of the preseason

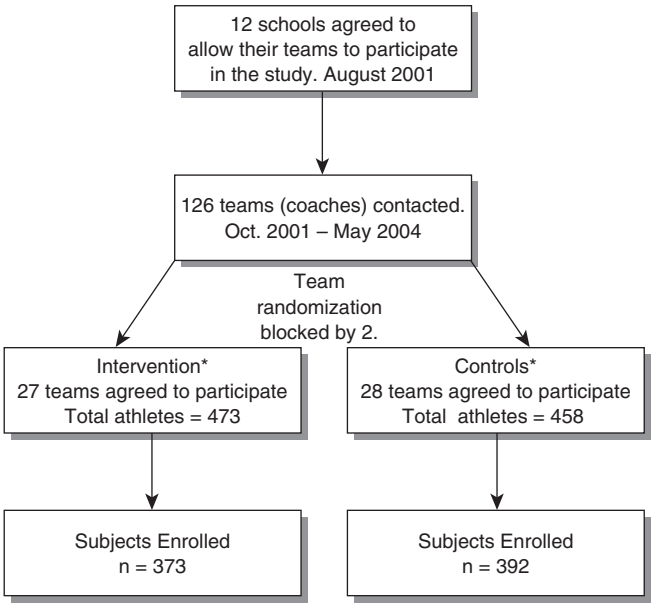

Figure 1. Subject recruitment and randomization.

drills and practices without restrictions due to a prior injury. Finally, each subject (and the parents if under age 18 years) had to complete the informed consent and Health Insurance Portability and Accountability Act of 1996 (HIPAA) forms.

Subject Data

At each school, our on-site ATCs collected the anthropometric data (gender, height, weight, ankle laxity, and leg dominance), as well as sprain history, on each subject (Table 1). Height was measured with a stadiometer (±0.5 cm). Weight was measured on digital platform scale (±0.1 lb).

Each subject was required to complete a detailed questionnaire regarding whether he or she had a prior ankle sprain and whether that sprain occurred during the previous 12 months. When possible, this information was cross-checked with the injury information compiled during the previous school year by our on-site ATCs. To determine ankle ligament laxity, the trainer performed an anterior drawer test on the ankle with the subject in a seated position. Leg dominance was determined by asking the athlete which leg he or she would use to kick a ball.

The configuration of the medial longitudinal arch was determined by using the Feiss line, which was measured when the athlete stood with his or her weight on both feet.[19] The Feiss line is a line drawn from the medial malleolus to the head of the first metatarsal. If the navicular tubercle intersected the line, the arch was graded as neutral. If the tubercle was above the line, the arch was graded as supinated. If the tubercle was below the line, the arch was graded as pronated.

TABLE 1
Subject Demographics (N = 765)[a]

Variable	Controls (n = 392)	Intervention (n = 373)
Gender		
Female	262 (66.8)	261 (69.9)
Male	130 (33.1)	112 (30.1)
Age, y	16.6 ± 1.1	16.4 ± 1.2
Height, cm		
Female	167.4 ± 6.0	166.1 ± 6.9
Male	173.7 ± 11.7	174.8 ± 10.4
Weight, kg		
Female	61.2 ± 7.0	60.5 ± 7.4
Male	69.4 ± 11.6	71.6 ± 10.8
Level of competition		
Varsity	317 (80.8)	320 (85.7)
Subvarsity	58 (14.7)	22 (5.8)
Freshman	17 (4.3)	31 (8.3)
Previous ankle injury		
Yes	93 (23.7)	89 (23.8)
No	299 (76.3)	284 (76.2)
Leg dominance		
Right	352 (89.7)	336 (90.0)
Left	40 (10.2)	37 (10.0)
Arch type		
Pronated	126 (32.1)	98 (26.2)
Neutral	244 (62.2)	248 (66.4)
Cavus	22 (5.6)	27 (7.2)
Use of ankle supports		
Yes	74 (18.9)	70 (18.7)
No	318 (81.1)	303 (81.3)
Ankle laxity (drawer test)		
≤ 5 mm	387 (99.3)	364 (97.9)
5+ mm	5 (0.7)	9 (2.1)

[a]All data are presented as n (%), except age, height, and weight, which are presented as mean ± SD.

The Balance Training Program

Subjects in the intervention group performed a 5-phase balance training program, the components of which are shown in Table 2. The program was based on a compilation of the rehabilitation and balance training protocols validated and published in prior studies.[5,10,11,15,18,20,22,25] Phases 1 through 4 consisted of 5 exercise sessions per week for 4 weeks before the start of the season. In phase 5 (maintenance phase), the subjects performed the program 3 times per week for 10 minutes throughout the competitive season. In all phases, each exercise was performed for 30 seconds, and the legs were alternated during a 30-second rest interval between each exercise.

The exercise program included (1) maintaining a single-leg stance on a flat surface with eyes open and closed; (2) performing functional sport activities such as throwing, catching, and dribbling on 1 leg; (3) maintaining double-leg stance while rotating the balance board; (4) maintaining a single-leg stance on the balance board with eyes open and closed; and (5) performing functional sport activities while in single-leg stance on the board (Figures 2-6). The balance board that was used consisted of a wooden disk 16 inches in diameter with a 4-inch half sphere attached to the bottom (Fitter International, Calgary, Alberta, Canada). The sphere allowed approximately 17° of angulation in all planes.

Members of each team were encouraged to take part in the intervention program as a group and were given the option of performing the exercises before or after practice. Teams did not perform the intervention on competition days. If a subject missed 4 consecutive balance training sessions, he or she was considered noncompliant with the balance training protocol. Control subjects did not take part in any prevention or balance training exercises beyond their normal conditioning exercises as directed by their coaches.

Definitions and Data Collection

The ATCs assigned to each school monitored each subject throughout the season and recorded all athlete exposures, acute sprains, use of ankle supports, and compliance with the intervention protocol. An athlete exposure was defined as any coach-directed competition, practice, or conditioning session. Ankle supports were defined as any external support such as athletic tape or lace-up or hard-shell braces.

The definitions of an acute injury and injury severity were similar to the criteria used by Powell and Barber-Foss[21] in their studies on high school athletes. For this study, an ankle sprain was defined as trauma that (1) disrupted the ligaments of the ankle; (2) occurred during a coach-directed competition, practice, or conditioning session; and (3) caused the athlete to miss the rest of a practice or competition or miss the next scheduled coach-directed practice or competition.

Injury severity was determined by counting the calendar days lost because of the sprain. Sprains were classified as minor (1-7 days lost), moderate (8-21 days lost), or severe (more than 21 days lost). The ATCs at the school determined the occurrence, diagnosis, and severity of each sprain.

An injured athlete was only allowed to return to activity under the direction of his or her athletic trainer and physician. To return, each injured athlete was required to demonstrate full ankle strength and pain-free range of motion. In addition, each injured athlete had to be able to complete a running program that included a series of functional activities (running, jumping, hopping, and cutting drills) similar to the demands of his or her individual sport.

Data Analysis

Ankle sprain rates were summarized as both the percentage of athletes injured and sprains per 1000 athlete exposures. Athlete exposures were tabulated for each noninjured subject throughout the sports season and for injured subjects up to the date of their first acute ankle sprain. A small number (n = 11) of athletes dropped out of the study when they stopped participating on their interscholastic team and were included in the analysis through the last day of their team membership. A total of 34 intervention subjects were classified as noncompliant (missed 4 consecutive balance training sessions). All subjects were included in the analysis under the intent-to-treat principle, which mandates that all subjects

TABLE 2
The Balance Training Program[a]

Phase	Surface	Eyes	Exercise
I	Floor	Open	Single-leg stance
Week 1		Open	Single-leg stance while swinging the raised leg
		Open	Single-leg squat (30°-45°)
		Open	Single-leg stance while performing functional activities (dribbling, catching, kicking)
II	Floor	Closed	Single-leg stance
Week 2		Closed	Swinging the raised leg
		Closed	Single-leg squat (30°-45°)
III	Board	Open	Single-leg stance
Week 3		Open	Swinging the raised leg
		Open	Single-leg squat (30°-45°)
		Open	Double-leg stance while rotating the board
IV	Board	Closed	Single-leg stance
Week 4		Open	Swinging the raised leg
		Open	Single-leg squat (30°-45°)
		Open	Single-leg stance while rotating the board
V	Board	Closed	Single-leg stance
Week 5+		Open	Single-leg squat (30°-45°)
		Open	Single-leg stance while rotating the board
		Open	Single-leg stance while performing functional activities (dribbling, catching, kicking)

[a]Phases I through IV were performed 5 days per week. Phase V was performed 3 days per week for the rest of the season. Each exercise was performed for a duration of 30 seconds per leg, and legs were alternated during a rest period of 30 seconds between repetitions.

Figure 2. Single-leg stance with eyes open.

Figure 3. Single-leg stance while dribbling.

Figure 4. Double-leg stance while rotating the board.

Figure 5. Balancing on the board while the eyes are closed.

are included in all analyses, regardless of whether they completed the intervention program.

Various statistical procedures were performed on the data using $P < .05$ as the level of significance. Ankle sprain rates were estimated using the methods of Kaplan and Meier survival analysis and compared between the intervention and control groups using a log-rank test. The Cox Proportional Hazards model was used to examine the relationship between ankle sprains and several independent variables (intervention, gender, height, weight, sport, etc). In addition, Fisher exact tests were used to determine if the intervention program was equally effective for subjects with and without a history of an ankle sprain. All statistical analyses were performed using SAS software, version 6.12 (SAS Institute, Cary, NC).

RESULTS

Subject Population

The characteristics and demographics for the subjects in the intervention and control groups were similar and are summarized in Table 1. Although the number of male and female athletes recruited for the study was comparable, 542 (68.3%) of the subjects who ultimately enrolled were girls. This finding did not affect the analysis, however, because the percentage of girls in the intervention and control groups (69.9% vs 66.8%) was similar.

Description of the Ankle Sprains

Sixty-two of the 765 subjects (8.1%) sustained an acute ankle sprain during their sports season (Table 3). Overall, the rate of ankle sprains was 1.51 per 1000 exposures. Fifty-six (90.3%) were lateral ankle sprains, 4 (6.4%) were medial sprains, and 2 (3.2%) were syndesmotic sprains.

The mean number of days lost from the sprains was 7.6 days (range, 2-26 days). A majority (64.5%) of the ankle sprains were minor and caused the athlete to miss 1 to 7 days, whereas 29% were classified as being of moderate severity (the athlete missed 8-21 days), and 6.4% were severe (the athlete was out for more than 21 days). Three subjects sustained a sprain near the end of the season and did not return to competition before the season ended. In these cases, the trainer stopped counting days lost on the last day the team practiced or competed.

Balance Training Subjects Versus Control Subjects

Kaplan-Meier survival analysis documented the exposure date of each sprain and the number of athletes exposed for that particular day, thereby calculating the relative risk of sprain during the course of the season (Figure 7). The sprain rates for the intervention subjects were significantly lower than for controls ($\chi^2 = 4.00, df = 1, P = .045$). The risk of ankle injury for subjects taking part in the balance training program was 62.0% (95% confidence interval [CI], 37.8%-101.7%) of that in the control group (Table 4).

Figure 6. Balancing on the board while performing functional activities (dribbling).

TABLE 3
Description of the Ankle Sprains

	n	%
Ankle sprains	62	8.1
Exposures	41 078	
Sprains/1000 exposures	1.51	
Severity (days lost)	Mean = 7.6 + 5.3	
Mild	40	64.5
Moderate	18	29.0
Severe	4	6.4
Type of sprain		
Lateral	56	90.3
Medial	4	6.4
Syndesmotic	2	3.2

In athletes without previous ankle sprain, 7.7% (23 of 299) of the controls and 4.2% (12 of 284) of the subjects taking part in the intervention sustained an ankle sprain. The risk of ankle injury in the intervention group was 54.9% (95% CI, 27.9%-108.3%) of that in the control group. Although the training program appeared to reduce the incidence of ankle sprains in subjects without a history of ankle sprain, these results did not achieve significance ($\chi^2 = 3.42$, $df = 1$, $P = .059$). However, the small number of sprains and the sample size limited the statistical power

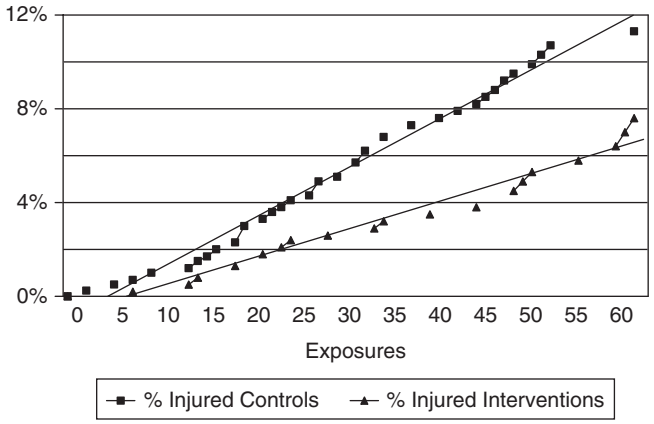

Figure 7. Rate of ankle sprains for high school subjects in the control and intervention groups. The rate of ankle sprains was significantly lower in subjects in the intervention group. (Kaplan-Meier survival estimate: $\chi^2 = 4.00$, $df = 1$, $P = .045$.)

in this analysis to detect any difference in injury rates between the 2 groups.

There were no adverse events from participating in the balance training program. Specifically, the on-site trainers did not observe or report any injuries from athletes who fell off of the board during the balance training.

Effect of the Independent Variables on the Risk of Ankle Sprain

The effect each variable had on the rate of ankle sprain is shown in Table 5. The risk of sustaining an ankle sprain was twice as high (risk ratio, 2.14; 95% CI, 1.25-3.65; $P = .005$) for subjects who had sustained an ankle sprain within the previous 12 months. Taking part in the intervention program significantly reduced the risk of an ankle sprain (risk ratio, 0.56; 95% CI, 0.33-0.95; $P = .033$). This finding indicates that the intervention program was very effective in reducing the number of ankle sprains.

The remaining variables evaluated, including gender, sport, leg dominance, use of ankle supports, and ankle laxity, did not have a significant effect on the rate of ankle sprains (Table 5).

Ankle Sprain Severity

The mean number of days lost was 5.8 ± 5.5 days for subjects in the intervention group and 8.1 ± 6.6 days for subjects in the control group. The distribution of ankle sprains by severity (mild, moderate, severe) is summarized in Table 6. The percentage of minor sprains in the intervention group was higher than in the control group (74% vs 59%), whereas the percentage of moderate sprains in the intervention group was lower than in the control group (22% vs 33%).

A Fisher exact test was used to determine whether there was a significant difference in the distribution of injury

TABLE 4
Rate of Ankle Sprains for Control and Intervention Subjects

	Subjects (n)	Ankle Sprains	Rate per Player (%)	Exposures	Sprains/1000 Athletic Exposures
Controls	392	39	9.9	20 828	1.87
Intervention	373	23	6.1[a]	20 250	1.13
Total	765	62	8.1	41 078	1.51

[a]The risk ratio for subjects in the intervention group was 62% of that of controls.

TABLE 5
Relationship of Independent Variables and the Risk of Ankle Sprain for High School Soccer and Basketball Players[a]

Variable	χ^2	*P*	Risk Ratio	95% CI
Balance training program	4.513	.033[b]	0.56	0.33-0.95
Age	0.007	.929	1.01	0.78-1.31
Level of competition	0.696	.404	0.76	0.41-1.42
Use of ankle support	3.821	.051	1.75	0.99-3.09
Height	0.564	.452	0.79	0.43-1.45
Weight	0.293	.588	1.03	0.90-1.18
Body mass index	0.495	.481	0.74	0.32-1.69
Leg dominance	1.490	.222	0.78	0.15-1.55
History of ankle sprain	7.891	.005[b]	2.14	1.25-3.65
History of knee injury	0.395	.529	0.74	0.29-1.88
Arch type, pronated	0.918	.338	0.75	0.43-1.33
Arch type, supinated	0.040	.840	0.89	0.31-2.55
Ankle laxity	0.074	.785	0.75	0.10-5.69
Gender	0.330	.565	0.81	0.40-1.63
Sport	1.232	.266	1.39	0.77-2.48

[a]Cox Proportional Hazards Model (χ^2 = 30.032, *df* = 15); CI, confidence interval.
[b]Denotes a significant value ($P < .05$).

severity between both groups. However, because of the small number of sprains in the moderate and severe categories, these categories were collapsed into a single category (more than 7 days lost). After collapsing the data, no difference was detected ($P = .281$) in sprain severity.

DISCUSSION

The primary objective of this study was to determine whether a balance training program could reduce the rate of ankle sprains in high school athletes. The results of this study document that a simple, inexpensive, balance training program performed during a high school sport season will reduce the rate of ankle sprains by 38% in male and female high school soccer and basketball players. This result has several important ramifications. First, the age group included in this study represents a large (1.7 million) population of athletes participating in high school soccer and basketball programs. Second, ankle sprains represent the highest rate of time loss injuries in this population of athletes. A decrease of 38% of ankle sprains in this group of high school soccer and basketball players (as found in this study) would result in a reduction of $26 million in direct health care costs and $380 million in indirect costs per year if the program were used on a national level for these 2 sports alone. Third, many of the athletes in high schools across the country do not have access to the equipment or the skilled personnel necessary to participate in an ankle sprain prevention program. Fourth, the balance boards are not expensive. Balance boards similar to those used in this study can be purchased for $30 to $60 and will last for several years. Purchasing 10 to 12 balance boards would allow many members of a team to use the boards at the same time, thus causing little disruption of other team activities and practices. Finally, the 5-phase program used in this study is time efficient and can easily be adapted to most athletic team practices and physical education class settings.

Male and female high school (adolescent) athletes in the United States are a population that has been sparsely studied regarding prevention of ankle sprains. In fact, this study is the first to show that balance training, as a single intervention, will significantly reduce ankle sprains in this population. One prior study also used adolescent athletes to evaluate the efficacy of balance training (an ankle disk program) for reducing ankle sprains in female team handball players (ages 16-18 years).[28] However, their prevention program also included one warm-up activity for each muscle group to ensure a thorough warm-up and training of all muscle groups. The authors found that the number of ankle sprains was significantly lower in the intervention group and concluded that the specific training of balance and proprioception had an important role in the prevention of ankle sprains in young female handball players. However, they could not determine whether the balance training or the regular warm-up was the major cause for the reduction in injury rates.

The second objective of this study was to determine whether a balance training program was equally effective in reducing the rate of ankle sprains in subjects with and without a history of an ankle sprain. None of the prior studies has been able to document that a proprioceptive training program will significantly reduce the incidence of ankle sprains in athletes without a prior sprain.[4,11,25,27-29] Our results suggest that a balance training program will reduce the rate of ankle sprains in athletes who have not had a prior ankle sprain. However, our results approached ($P < .059$) but did

TABLE 6
Distribution of the Ankle Sprains by Severity (Days Lost)[a]

	Minor, 1-7 d		Moderate, 8-21 d		Severe, >21 d		Total
Group	n	%	n	%	n	%	n
Intervention	17	73.9	5	21.7	1	4.3	23
Control	23	58.9	13	33.3	3	7.6	39
Total	40	64.5	18	29.0	4	6.0	62

[a]There were no significant differences in injury severity between the 2 groups. Because of the small number of injuries, the category of Minor injuries was compared with the combined categories of Moderate and Severe injures. Fisher exact test, $P = .281$.

not attain statistical significance. This finding was attributed in large part to the fact that there were fewer sprains (n = 62) than the number we projected (n = 87) based on the incidence of acute sprains reported in other studies.[3,7,21,24,26]

The results substantiate that a balance training program was effective in significantly reducing the rate of recurrent ankle sprains in those high school athletes who had prior ankle sprains. This result is in accord with the results of prior studies. Verhagen et al,[26] who studied the effect that a 36-week balance board training program had on reducing ankle sprains in adult Dutch volleyball players, found that the number of self-reported ankle sprains was significantly lower in athletes completing the intervention program. This result, however, was seen only in players with a history of an ankle sprain.

Tropp et al[25] compared the efficacy of a semirigid ankle orthosis and ankle disk training for reducing ankle sprains. However, the ankle disk training program was only given to the 65 athletes who had previous ankle problems. Both the semirigid orthosis and the ankle disk program significantly reduced the number of ankle sprains in those with prior ankle sprains.

In 1997, Bahr et al[4] reported on a 3-year cohort study that evaluated a proprioceptive prevention program that included a didactic session on risk factors, a 2-hour training session on a balance board for players with previous ankle sprains, and technical training that emphasized safe takeoff and landing techniques. They found that the incidence of ankle sprains was reduced by 47% from the first to the third years, but they could not determine to what degree each of the program's elements contributed to the overall results.

Three other studies also examined the effect that balance training had on athletes with a history of an ankle sprain. Each of these studies also found that the intervention group, which did a balance training program, had a significantly lower rate of re-sprains compared with the control group.[11,23,29]

The third goal of this study was to examine the relationship that various independent variables had on the risk of sustaining an ankle sprain. Sustaining an ankle sprain within the previous 12 months more than doubled the risk of another sprain (risk ratio, 2.14). This finding is consistent with previous publications that reported that sustaining an ankle sprain predisposes a person to a subsequent ankle sprain.[9,24,29]

The variable that was associated with the lowest risk of an ankle sprain was performing the balance training program. This program reduced the risk of injury by nearly half (risk ratio, 0.56). This finding, coupled with the risk ratio of 2.14 for reinjury reported above for those who had prior sprains, further emphasizes the importance of performing balance training exercises to reduce the rate of ankle sprains.

It is interesting that the use of ankle supports appeared to lead to an increase in the risk of ankle sprain. However, this finding should be interpreted with caution. We defined ankle support as any tape or brace used by the athlete. We suspect that a number of athletes used braces that they had purchased on their own that provided limited support. In addition, some athletes relied on coaches and teammates to tape them when they competed away from their own school. We have no doubt that if equivalent, well-constructed braces were used on all athletes and taping was done only by an ATC, we would not have found that the risk of ankle sprains was higher in subjects who used ankle supports.

The last objective of the study was to determine whether the balance training program would reduce the severity of ankle sprains. We found that the balance training program did not affect the severity of the sprain. Specifically, it did not reduce the mean number of days lost and did not affect the distribution of sprains classified as mild, moderate, or severe. This finding is similar to that of Verhagen et al,[27] who found that the average time lost from volleyball after an ankle sprain was not affected by taking part in a balance training program.

Study Limitations

Recall bias may have occurred with the subjects when they completed the self-report questionnaire regarding their sprain history. We tried to minimize this bias by reviewing the responses with each subject and cross-checking responses whenever possible with the school injury records from previous sport seasons.

The lack of blinding may also be a limitation. Subjects performing the intervention knew they were doing so to prevent sprains. In addition to the lack of subject blinding, the ATCs at the schools knew which teams were in the control and intervention groups. Such limitations have been discussed in reviews,[9,24,26] which have concluded that these problems are inherent in these types of studies.

In this study, female subjects outnumbered male subjects by a ratio of 2 to 1. Before each season, equal numbers

of male and female teams were contacted and recruited to participate in the study, so there were no logistical reasons why more female subjects were enrolled. However, we did notice that the parents of female athletes seemed more interested in having their daughters take part in this research. This may be because of the intense reporting during the past several years on injuries such as anterior cruciate ligament tears in young female basketball and soccer players. In general, they seemed to be more diligent in asking questions during the parent meetings we attended and in returning all informed consent and HIPAA documents before the start of the sport season so that their daughters could participate in the study.

CONCLUSIONS

This study documented that a balance training program, implemented throughout a sports season, will reduce the rate of ankle sprains by 38% in high school basketball and soccer players. The balance training program included simple exercises and employed an inexpensive device that should be readily available to high school and adolescent athletes across the United States. Further research is needed to determine whether this exercise program can significantly reduce the rate of ankle sprain in athletes without a history of a sprain or reduce ligament sprains in the knee and other lower extremity joints in high school athletes.

ACKNOWLEDGMENT

The authors gratefully acknowledge the work of Glen Leverson, PhD, Biostatistician, at the University of Wisconsin Medical School who provided consultation on the research design and performed the statistical analyses for this study. Funding for this study was provided by the University of Wisconsin Surgical Associates Research Fund and UW Sports Medicine Classic Fund.

REFERENCES

1. American Academy of Orthopaedic Surgeons. The foot and ankle. American Academy of Orthopaedic Surgeons Web site. Available at: http:// orthoinfo.aaos.org/fact/thr_report.cfm?thread_id=100&topcategory= Foot. Accessed May 3, 2005.
2. American Academy of Orthopaedic Surgeons. Sprained ankle may not be a minor injury. American Academy of Orthopaedic Surgeons Web site. Available at: http://www.aaos.org/wordhtml/2001news. Accessed January 23, 2002.
3. Bahr R. Can we prevent ankle sprains? In: MacAuley D, Best TM, eds. *Evidence-Based Sports Medicine*. London, England: BMJ Books; 2002:470-490.
4. Bahr R, Lian O, Bahr IA. A twofold reduction in the incidence of acute ankle sprains in volleyball after the introduction of an injury prevention program: a prospective cohort study. *Scand J Med Sci Sports*. 1997;7:172-177.
5. Bernier JN, Perrin DH. Effect of coordination training on proprioception of the functionally unstable ankle. *J Orthop Sports Phys Ther*. 1998;27:264-275.
6. Braun BL. Effects of ankle sprain in a general clinic population 6 to 18 months after medical evaluation. *Arch Fam Med*. 1999:8:143-148.
7. Garrick JG. The frequency of injury, mechanisms of injury, and epidemiology of ankle sprains. *Am J Sports Med*. 1977;5:241-242.
8. Gerber JP, Williams GN, Scoville CR, Arciero RA, Taylor DC. Persistent disability associated with ankle sprains: a prospective examination in an athletic population. *Foot Ankle Int*. 1998;19:653-660.
9. Handoll HHG, Rowe BH, Quinn KM, de Bie R. Interventions for preventing ankle ligament injuries. *Cochrane Database Syst Rev*. 2001;3: CD000018. Available at: http://gateway2.ovid.com/ovidweb.cgi.
10. Hoffman M, Payne VG. The effects of proprioceptive ankle disk training on healthy subjects. *J Orthop Sports Phys Ther*. 1995;21:90-93.
11. Holme E, Magnusson SP, Becher K, Bieler T, Aagaard P, Kjaer M. The effect of supervised rehabilitation on strength, postural sway, position sense and re-injury risk after acute ankle ligament sprain. *Scand J Med Sci Sports*. 1999;9:104-109.
12. Hosea TM, Carey CC, Harrer M. The gender issue: epidemiology of ankle injury in athletes who participate in basketball. *Clin Orthop Relat Res*. 2000;372:45-49.
13. Kannus P, Renstrom P. Treatment for acute tears of the lateral ligaments of the ankle: operation, cast, or early controlled mobilization. *J Bone Joint Surg Am*. 1991;73:305-312.
14. Lassiter TE, Malone TR, Garrett WE. Injury to the lateral ankle ligaments of the ankle. *Orthop Clin North Am.* 1989;20:629-640.
15. Lephart SM, Pincivero DM, Giraldo JL, Fu FH. The role of proprioception in the management and rehabilitation of athletic injuries. *Am J Sports Med*. 1997;25:130-137.
16. McGuine TA, Keene JS. Do proprioceptive training programs reduce the risk of ankle sprains in athletes? *Int Sport Med J.* 2003:4;311-319.
17. National Federation of High Schools. 2003-2004 high school sport participation survey. National Federation of High Schools Web site. Available at: http://www.nfhs.org/participation/sportspart01.htm. Accessed March 28, 2005.
18. National Athletic Trainers Association. High school basketball players risk injury this season [press release]. September 1996.
19. Palmer ML, Epler ME. *Clinical Assessment Procedures in Physical Therapy.* Philadelphia, Pa: J. B. Lippincott; 1990:301-302.
20. Pincivero D, Gieck J, Saliba E. Rehabilitation of a lateral ankle sprain with cryokinetics and functional progressive exercise. *J Sport Rehabil*. 1994;2:200-207.
21. Powell JW, Barber-Foss KD. Injury patterns in selected high school sports: a review of the 1995-1997 seasons. *J Athl Train*. 1999;34: 277-284.
22. Sheth P, Yu B, Laskowski ER, An KN. Ankle disk training influences reaction times of selected muscles in a simulated ankle sprain. *Am J Sports Med*. 1997;25:538-543.
23. Stasinopoulos D. Comparison of three preventive methods in order to reduce the incidence of ankle inversion sprains among female volleyball players. *Br J Sports Med.* 2004;38:182-185.
24. Thacker SB, Stroup DF, Branche CM, Gilchrist J, Goodman RA, Weitman EA. The prevention of ankle sprains in sports: a systematic review of the literature. *Am J Sports Med*. 1999;27:753-760.
25. Tropp H, Askling C, Gillquist J. Prevention of ankle sprains. *Am J Sports Med*. 1985;13:259-262.
26. Verhagen EALM, van Mechelen W, de Vente W. The effect of preventive measures on the incidence of ankle sprains. *Clin J Sport Med*. 2000;10:291-296.
27. Verhagen E, van der Beek A, Twisk J, Bouter L, Bahr R, van Mechelen W. The effect of a proprioceptive balance board training program for the prevention of ankle sprains. *Am J Sports Med.* 2004;32: 1385-1393.
28. Wedderkopp N, Kaltoft M, Lundgaard B, Rosendahl M, Froberg K. Prevention of injuries in young female players in European team handball: a prospective randomized study. *Scand J Med Sci Sports*. 1999;9:41-47.
29. Wester JU, Jespersen SM, Nielsen KD, Neumann L. Wobble board training after partial sprains of the lateral ligaments of the ankle. *J Orthop Sports Phy Ther*. 1996;23:332-336.
30. Yeung MS, Chan KM, So CH, Yuan WY. An epidemiological survey on ankle sprains. *Br J Sports Med.* 1994;28:112-116.