ORIGINAL ARTICLE

Single leg balance test to identify risk of ankle sprains

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Br J Sports Med 2006;**40**:610–613. doi: 10.1136/bjsm.2005.024356

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Accepted 28 March 2006
Published Online First 10 May 2006

Background: Ankle sprains are a common and potentially disabling injury. Successful prediction of susceptibility to ankle sprain injury with a simple test could allow ankle sprain prevention protocols to be initiated and help prevent disability in the athletic population.
Objective: To investigate the ability of the single leg balance (SLB) test, carried out at preseason physical examination, to predict an ankle sprain during the autumn sports season.
Design: Prospective cohort study
Setting: High school varsity athletics and intercollegiate athletics.
Main outcome measure: Ankle sprains in athletes with positive SLB tests.
Results: The association between a positive SLB test and future ankle sprains was significant. Controlling for confounding variables, the relative risk for an ankle sprain with a positive SLB test was 2.54 (95% confidence interval, 1.02 to 6.03). Athletes with a positive SLB test who did not tape their ankles had an increased likelihood of developing ankle sprains. The relative risk for ankle sprain for a positive SLB test and negative taping was 8.82 (1.07 to 72.70). A history of previous ankle injury was not associated with future ankle sprains in this study. The κ value for interrater reliability for the SLB test was 0.898 ($p<0.001$).
Conclusions: An association was demonstrated between a positive SLB test and ankle sprain. In athletes with a positive SLB test, not taping the ankle imposed an increased risk of sprain. The SLB test is a reliable and valid test for predicting ankle sprains.

Ankle sprains are a common and potentially disabling injury. The ankle is one of the most injured joints, especially in American football, soccer, and volleyball.[1–4] Ankle sprain accounts for 12–20% of all sports injuries.[5–7] It causes 16% of all sports injury time loss.[8]

Disability from ankle sprains in athletes can be severe, with 40% of patients having dysfunction that persists for as long as six months after the injury.[9] This dysfunction includes a reduction in proprioception after acute ankle sprains.[10] In addition, athletes with multiple ankle sprains have significantly decreased kinaesthetic awareness and proprioception.[11 12] This loss in proprioception is a potential risk factor for re-injury.[13]

Stabilometry is a reliable and non-invasive technique developed to assess equilibrium disturbances. It records body sway with pressure sensors set at the vertex of regular triangle plates. Numerous studies have used stabilometry equipment to record differences between injured and uninjured ankles, as well as changes after injury in postural sway and proprioception.[4 10 14] Athletes with higher stabilometry scores have been shown to be at increased risk of sustaining an ankle injury.[15 16]

Stabilometry equipment is expensive and not readily available for preparticipation examination (PPE) screening of athletes. A screening tool available at a low cost and able to predict ankle sprains would be very useful. The single leg balance test (SLB test), described as early as 1965, may be such a tool, as it can be carried out inexpensively and with limited training.[17]

The goals of this prospective cohort study of male and female high school and college athletes were to determine whether the SLB test can predict future ankle sprains, whether a history of previous ankle sprain is a predictor of re-injury of the ankle, and whether the interobserver reliability of the SLB test is satisfactory.

To our knowledge, this is the first attempt to measure postural sway using the SLB test in asymptomatic athletes and to correlate these findings with frequency of ankle injury. Successfully predicting susceptibility to ankle sprain injury in athletes with this simple test could allow specific training prevention protocols to be initiated. This could prevent disability and decrease health care costs in the athlete population.

METHODS

Participants

In the autumn season, all athletes in men's American football, men's and women's soccer, and women's volleyball were invited to participate from one high school and three local colleges. Athletes were enrolled prospectively during the PPE, when the primary investigator was available. From this convenience sample, 230 male and female athletes were screened at the end of their PPE using the SLB test. The primary investigator was a clinician who evaluated all athletes' SLB tests and was blinded to the PPE results. Athletes were excluded from the study if they were not cleared for athletics without restriction during the PPE for any reason, if they had any previous ankle fracture, or if they had an ankle sprain within the previous six weeks. No athlete wore ankle braces during the study. Participants with a history of ankle taping were requested to continue to tape. The participants were followed for 14 weeks until the completion of the fall season.

Testing

The primary investigator was blinded to the athlete's previous ankle injury status. The SLB test was defined as standing on one foot without shoes with the contralateral knee bent and not touching the weight bearing leg; the hips were level to the ground; the eyes open and fixed on a spot marked on the wall; and then the eyes are closed for 10 seconds. The athlete reports any sense of imbalance. The investigator notes if the athlete's legs touched each other, the feet moved on the floor, the foot touches down, or the arms moved from their start

Abbreviations: ATC, certified athletics trainer; PPE, preparticipation examination; SLB, single leg balance

Table 1 Demographic characteristics of the study population

Sex	Female	80 (34.8%)
Sport	Football	100 (43.5%)
	Women's soccer	54 (23.5%)
	Men's soccer	50 (21.7%)
	Volleyball	26 (11.3%)
Age (years)	Mean (SD)	18.4 (2.2%)
	Range	14 to 21
Question 1	Do you tape your ankle(s)? Number answering yes	125 (54.3%)
Question 2	Have you had an ankle sprain in the last two years? Number answering yes	106 (46.1%)
Question 3	If you had more than one ankle sprain, how many? Number with more than one sprain	68 (29.8%)
Question 4	When you had your last ankle sprain, what did you do for treatment? Number who went to ATC (% of 106)	44 (41.5%)
Question 5	If you had an ankle sprain did you do balance retraining? Number answering yes (% of 106)	34 (32.1%)

Values are n (%) unless stated otherwise.
ATC, certified athletics trainer.

position.[18] If the athlete had a positive test (failed to remain balanced or described a sense of imbalance) during the first trial, a second trial was carried out, with the results of the second trial counting (positive or negative) for analysis. Both legs were tested. An SLB test was considered positive if the athlete was unable to carry out the test on either or both legs.

Informed consent

Consent for participation was obtained from the athletes or from the parents of athletes under 18 years of age.

Questionnaire

A questionnaire, which included baseline information on age, sex, school, and five screening questions, was distributed during the PPE.

The five questions were:

Question 1: Do you tape your ankle(s)?

Question 2: Have you had an ankle sprain in the last two years?

Question 3: If you had more than one ankle sprain, how many?

Question 4: When you had your last ankle sprain, what did you do for treatment?

Question 5: If you had an ankle sprain did you do balance retraining?

Collection of results

Each school (one high school and three colleges) had a certified athletics trainer (ATC) who was blinded to the SLB test score. The ATC from each school reported the ankle sprains on previously coded forms. For logistical reasons at each school, all athletes who chose to be taped or who were injured were taped more than 30 minutes before practice. The ATCs were requested to note any athlete with a negative answer to a history of taping who requested ankle taping. An ankle sprain injury was defined as trauma that disrupted the structures of the ankle and which occurred during a team sponsored practice or competition session, and caused the athlete to miss the rest of practice or competition, or miss the next scheduled team practice or competition. Ankle injuries were confirmed by examination by the primary investigator. All ankle sprains were cared for appropriately. Athletes with a sprain during the season were not counted more than once in the study.

Table 2 Distribution of positive and negative single leg balance test

Category		Positive SLB test	Negative SLB test	Ankle sprains
Sex	Female	42	38	12
	Male	65	85	16
School	High school	27	33	7
	College	80	90	21
Sport	Football	48	52	8
	Men's soccer	17	33	8
	Women's soccer	30	24	9
	Volleyball (women)	12	14	3

SLB, single leg balance.

Table 3 Single leg balance test and ankle sprains

		Ankle sprain	
		Yes	No
Positive SLB test	Yes	19	88
	No	9	114

SLB, single leg balance.

Reliability

An interrater reliability test was carried out on a separate occasion on uninjured athletes not participating in the study. Two people (the primary investigator and an ATC) simultaneously observed each athlete undertake the SLB test. The athlete followed the previously outlined protocol for testing except that two tests were done on both ankles. Each examiner was blinded to the other's results. The test was scored positive or negative.

Statistical analysis

The analysis was done using SPSS v.11.5. We used the χ^2 test or Fischer's exact test when the expected frequency was less than 5 in one square of the 2×2 χ^2 test. The Mantel-Haenszel method was used when controlling for confounding variables.

Power calculations for a β value of 0.2 and an α value of 0.05, with an estimated 18% sprain rate in a positive SLB test and a 10% rate in a negative SLB test, produced a sample size of 98 athletes needed in the positive and negative SLB test groups. Interobserver variability in the interpretation of the SLB test was computed using the κ statistic including 95% confidence intervals (CI).

RESULTS

During the course of the study, 28 ankle sprains were reported in the 230 athletes. Demographic and study test characteristics of the 230 athletes are listed in tables 1 and 2.

The association between a positive SLB test and ankle sprains was significant ($\chi^2 = 5.833$, df = 1, $p = 0.016$)

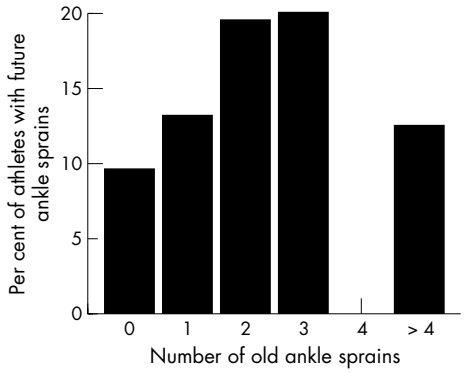

Figure 1 Previous injury and percentage with new sprains.

(table 3.) The relative risk (RR) for an ankle sprain with a positive SLB test during the PPE was 2.43 (95% CI, 1.15 to 5.14.) Controlling for sex, sport, school, previous history of ankle sprain, and taping, we found that the common odds ratio was 2.54 (95% CI, 1.02 to 6.03) ($p<0.05$).

Two subgroups of the athletes with a positive SLB test had notably higher relative risk of ankle sprains. The first subset was athletes who did not tape their ankle and may or may not have had a history of ankle sprains. Those with a positive SLB test were found to be significantly more likely to develop ankle sprains (Fischer's exact test, $\chi^2 = 6.124$, df = 1, p = 0.023). The relative risk for ankle sprain for a positive SLB test and negative taping was 8.82 (95% CI, 1.07 to 72.70). The second subset was athletes with no history of ankle sprains and who did not tape their ankles. Those with a positive SLB test had an increased relative risk of future ankle sprains (Fischer's exact $\chi^2 = 4.489$, df = 1, p = 0.03; RR = 7.18 (95% CI, 1.05 to 61.7)).

Athletes answering yes to the question ''Have you had an ankle sprain in the last two years?'' (n = 106) did not show an association with ankle sprains in the study ($\chi^2 = 1.568$, df = 1, p = 0.21; RR = 1.659 (95% CI, 0.75 to 3.68)). Athletes having an ankle sprain in the last two years were much more likely to have a positive SLB test ($\chi^2 = 13.176$, df = 1, p = 0.00). The odds ratio for a positive SLB test with a history of an ankle sprain compared with no history of an ankle sprain was 2.66 (95% CI, 1.56 to 4.54). We found that those athletes reporting two or more ankle sprains were more likely to have a positive SLB test ($\chi^2 = 5.873$, df = 1, p = 0.01). The odds ratio for a positive SLB test if an athlete reported two or more ankle sprains compared with those with fewer than two ankle sprains was 2.026 (95% CI, 1.14 to 3.60).

We did not find a significant relation between questions 3, 4, and 5 and ankle sprains. Figure 1 shows number of old ankle sprains with the percentage of new ankle sprains over the study period; 26.4% of the athletes saw a doctor for their last ankle sprain, 41.5% reported that they saw their trainer for their last ankle sprain, and only 8.5% said they saw both a doctor and a trainer for their last ankle sprain. Only 32.1% of athletes remembered doing balance training for their last ankle sprain. Neither question 4 nor question 5 showed a significant association with a positive SLB test.

Interrater reliability for the SLB test was investigated in 10 athletes similar to our study group but not participating in the study. The κ statistic was 0.898 (SE = 0.07, T score = 5.709, $p<0.01$). Table 4 shows the agreement between testers.

Table 4 Interrater reliability testing

		Tester 1		
		Positive SLB test	Negative SLB test	Total
Tester 2	Positive SLB test	16	1	17
	Negative SLB test	1	22	23
Total		17	23	40

SLB, single leg balance.

DISCUSSION

In this cohort study of high school and college age athletes over one autumn season, we were able to demonstrate prospectively an association between ankle sprains and a positive SLB test (common odds ratio = 2.54 (95% CI, 1.02 to 6.03)). Our finding is in agreement with that of three other investigations. Tropp *et al* studied male soccer players prospectively and found greater postural sway in those who sprained their ankles.[15] Leanderson *et al* reported that proprioceptive deficits could predict ankle injury susceptibility in basketball players.[19] Finally, McGuine *et al* showed that in high school basketball players preseason measurement of balance predicted susceptibility to ankle sprain injury.[16] The SLB test could thus be used to predict those at greatest risk of ankle sprains.

In previous studies, postural sway has been shown to predict the susceptibility to ankle sprains. Most high schools cannot afford stabilometry and a less expensive screening tool would be useful. We used the SLB test and were able to show a significant association between a positive SLB test and ankle sprains. We found a high relative risk in those athletes with a positive SLB test who did not have a history of ankle sprains nor taped their ankles (relative risk = 7.18 (95% CI, 1.06 to 61.7)). Additional studies in this group of previously uninjured athletes would be useful to determine whether they should be targeted for prevention. Further studies are also needed to determine whether balance training in this group would be beneficial.

We found that failure to tape the ankles was detrimental in athletes with a positive SLB test. Though taping the ankles during the study was not done in a uniform fashion and was done at least 30 minutes before practice, it appeared to be helpful in those athletes with a positive SLB test. Our findings support the role of taping in athletes at increased risk.

We were unable to find an association between a history of previous ankle sprain and new ankle sprain in this study. This was probably because most athletes with a history of ankle sprain (91%) reported taping their ankles. Other factors may also have played a role, such as balance training.

We did not find a significant sex difference in the SLB test results. The difference in sensitivity of SLB testing between male and female soccer players was not significant for this small sample. Future studies could explore differences between male and female athletes for the SLB test.

We found excellent agreement between the physician and the ATC in reproducibility testing, with a high κ statistic of 0.898. This is important for verification of generalisability of the SLB test to other settings and testers. We feel these findings support the excellent reliability of the SLB test.

The study has certain limitations. Some extrinsic factors were not available for analysis and this could have influenced the final results. We did not have a recording of daily weather, practice, or game exposure. Taping ankles and bracing ankles have been shown to be effective methods of preventing ankle sprains, and some but not all of the members of teams studied here were taped. We were unable and unwilling to prevent any athlete from taping their ankles. When taping was used, it was done more than 30 minutes before practice and in all cases taping was applied more than 60 minutes before any ankle injury. The value of taping becomes questionable after 20 to 30 minutes.[20 21] Logistical and financial limitations of most high school and smaller college training rooms prevent taping

What is already known on this topic?

- Ankle sprains are a common injury
- Athletes with increased centre of pressure on stabilometry are more likely to develop ankle sprains
- Stabilometry equipment is not widely available to high school and college sports medicine providers
- Treating ankle proprioception deficits reduces injury

What this study adds?

- The single leg balance test can be used in a preparticipation setting to identify athletes with an increase risk of ankle sprains

immediately before practice and re-taping every 30 minutes throughout practice and games. In the high schools the athletes would be taped before boarding a bus to games approximately one to two hours before the start of the game. No athletes were reported by the ATC to have started taping their ankle during the study.

Though no one with ankle weakness determined by PPE was included in the study, measurements of inversion and eversion strength were not obtained. It could be argued that the SLB test was a marker of a poor inversion to eversion strength ratio (a risk factor identified by Baumhauer *et al*) instead of poor proprioception at the ankle, as we had not undertaken stabilometry measurements on each subject.[22] Future studies looking at the ankle inversion to eversion strength ratio and the stabilometry score with the SLB test would help answer this question.

Conclusions

In this study of high school and college male and female athletes, preseason SLB test predicted susceptibility to ankle sprain injury. We found that lack of a previous ankle sprain and not taping increased the likelihood of ankle sprains in the athletes with a positive SLB test. While the SLB test served as a predictor of injury, the exact mechanism responsible for this increased risk of injury remains unknown. Further research is necessary to determine the mechanism and to refine the SLB test to increase its sensitivity. Prospective research needs to be undertaken to determine whether these results can be generalised to other athletic populations such as basketball players. In addition, prospective studies are needed to determine whether treatment of groups such as those without a previous injury but with a positive SLB test can be treated before an athletic season to limit injury.

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Competing interests: none declared

REFERENCES

1 **DeHaven KE**, Lintner DM. Athletic injuries: comparison by age, sport, and gender. *Am J Sports Med* 1986;**14**:218–24.
2 **Verhagen EA**, Van der Beek AJ, Bouter LM, *et al*. A one season prospective cohort study of volleyball injuries. *Br J Sports Med* 2004;**38**:477–81.
3 **Cohen AR**. Metzl JD. Sports-specific concerns in the young athlete: basketball, *Pediatr Emerg Care* 2000;**16**:462–8.
4 **Ostenberg A**, Roos H. Injury risk factors in female European football. A prospective study of 123 players during one season. *Scand J Med Sci Sports* 2000;**10**:279–85.
5 **Price RJ**, Hawkins RD, Hulse MA, *et al*. The Football Association medical research programme: an audit of injuries in academy youth football. *Br J Sports Med* 2004;**38**:466–71.
6 **Orchard JW**, Powell JW. Risk of knee and ankle sprains under various weather conditions in American football. *Med Sci Sports Exerc* 2003;**35**:1118–23.
7 **National Collegiate Athletic Association**. *Participation statistics report, 2002–2003*. Overland Park, KS: National Collegiate Athletic Association, 2003.
8 **Liu S**, Jason W. Lateral ankle sprains and instability problems. *Clin Sports Med* 1994;**13**:793–809.
9 **Gerber JP**, Williams GN, Scoville CR, *et al*. Persistent disability associated with ankle sprains: a prospective examination of an athletic population. *Foot Ankle Int* 1998;**19**:653–60.
10 **Leanderson J**, Eriksson E. 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**:370–4.
11 **Forkin DM**. Evaluation of kinesthetic deficits indicative of balance control in gymnasts with unilateral chronic ankle sprains. *J Orthop Sports Phys Ther* 1996;**23**:245–50.
12 **Garn S**, Newton R. Kinesthetic awareness in subjects with multiple ankle sprains. *Phys Ther* 1998;**68**:1667–71.
13 **Thacker SB**. The prevention of ankle sprains in sports. A systematic review of the literature. *Am J Sports Med* 1999;**27**:753–60.
14 **Tropp H**, Odenrick P. Postural control in single-limb stance. *J Orthop Res* 1988;**6**:833–9.
15 **Tropp H**, Ekstrand J, Gillquist J. Stabilometry in functional instability of the ankle and its value in predicting injury. *Med Sci Sports Exerc* 1984;**16**:64–6.
16 **McGuine TA**, Greene JJ, Best T, *et al*. Abstract balance as a predictor of ankle injuries in high school basketball players. *Clin J Sport Med* 2000;**10**:239–44.
17 **Freeman MA**, Dean MR, Hanham IM. The etiology and prevention of functional instability of the foot. *J Bone Joint Surg Br* 1965;**47B**:678–85.
18 **Bohannon RW**, Larkin PA, Cook AC, *et al*. Decrease in timed balance test scores with aging. *Phys Ther* 1984;**64**:1067–70.
19 **Leanderson J**, Wykman A, Eriksson E. Ankle sprain and postural sway in basketball players. *Knee Surg Sports Traumatol Arthrosc* 1993;**1**:203–5.
20 **Kirk T**, Saha S, Bowman LS. A new ankle laxity tester and its use in the measurement of the effectiveness of taping. *Med Eng Physics* 2000;**22**:723–31.
21 **Leanderson J**, Ekstam S, Salomonsson C. Taping of the ankle – the effect on postural sway during perturbation, before and after a training session. *Knee Surg Sports Traumatol Arthrosc* 1996;**4**:53–6.
22 **Baumhauer JF**, Alosa DM, Renstrom AF, *et al*. A prospective study of ankle injury risk factors. *Am J Sports Med* 1995;**23**:564–70.

COMMENTARY 1

The author is to be commended for attempting to provide a simple, reliable method, the single leg balance (SLB) test, to identify athletes at risk of ankle sprain during the upcoming season. Any apparent sex differences were not statistically significant owing to the small sample size, as pointed out in the discussion. This could be a point for future research. The SLB test, used in conjunction with a more detailed history of any clinical instability and a careful physical examination looking for muscle weakness, could help identify those individuals who would benefit from bracing/taping, muscle stengthening, and propioceptive training. There is great potential for future research.

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COMMENTARY 2

This was a very well done, concise study that indicates that future risk of ankle injury can be predicted reliably using a simple inexpensive test. The value of this study is wide ranging. It could reduce the number of ankle injuries, their costs, and time lost by athletes if instituted. Further studies, as suggested by the authors, may identify the pathophysiology of a positive test, further arming the sports medicine specialist with tools for prevention and treatment.

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