The Effectiveness of a Balance Training Intervention in Reducing the Incidence of Noncontact Ankle Sprains in High School Football Players

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Background: A high body mass index and previous ankle sprains have been shown to increase the risk of sustaining noncontact inversion ankle sprains in high school football players.

Hypothesis: Stability pad balance training reduces the incidence of noncontact inversion ankle sprains in football players with increased risk.

Study Design: Cohort study; Level of evidence, 2.

Methods: Height, body mass, history of previous ankle sprains, and current ankle brace/tape use were documented at the beginning of preseason training in 2 high school varsity football teams for 3 consecutive years (175 player-seasons). Players were categorized as minimal risk, low risk, moderate risk, and high risk based on the history of previous ankle sprain and body mass index. Players in the low-, moderate-, and high-risk groups (ie, any player with a high body mass index and/or a previous ankle sprain) were placed on a balance training intervention on a foam stability pad. Players balanced for 5 minutes on each leg, 5 days per week, for 4 weeks in preseason and twice per week during the season. Postintervention injury incidence was compared with preintervention incidence (107 players-seasons) for players with increased risk.

Results: Injury incidence for players with increased risk was 2.2 injuries per 1000 exposures (95% confidence interval, 1.1-3.8) before the intervention and 0.5 (95% confidence interval, 0.2-1.3) after the intervention ($P < .01$). This represents a 77% reduction in injury incidence (95% confidence interval, 31%-92%).

Conclusion: The increased risk of a noncontact inversion ankle sprain associated with a high body mass index and a previous ankle sprain was eliminated by the balance training intervention.

Keywords: inversion injury; proprioception; stability pad; body mass index (BMI)

In a previous study, it was demonstrated that previous ankle sprains and a high body mass index (BMI) were risk factors for noncontact inversion ankle sprains in high school football players.[8] Injury incidence was 19 times higher in players who had a previous ankle sprain and were overweight compared with players with no previous ankle sprain and who were of normal weight. These effects were independent of the player's playing position. The effect of previous ankle sprains on risk for subsequent injuries is well known.[4,9] Other data also indicated a possible association between a high BMI and risk of injury in American football.[3] However, the compounding effect of these factors had not been previously identified.

Previous research has indicated that the use of ankle braces can reduce the incidence of recurrent ankle sprains[5-7]; however, this was not apparent in the high school football players in our previous study.[8] Previous research has also indicated that the incidence of ankle sprains can be reduced by single-limb balance training on an ankle disk.[1,7,9,10]

It was theorized that the compounding effect of a previous ankle sprain and a high BMI on risk of a noncontact

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inversion ankle sprain in high school football players was owing to the combination of impaired ankle stability and inability to control proximal body mass during spontaneous dynamics movements.[8] It would follow that balance training in single-limb stance could counteract such impairments. Therefore, the purpose of this study was to determine if single-limb balance training on a foam stability pad can reduce the incidence of noncontact inversion ankle sprains in high school football players identified as being at increased risk.

METHODS

Two high school varsity football teams were followed for 3 seasons each from 2003 to 2005. Before each season, height, body mass, history of previous ankle sprains, and current ankle brace/tape use were documented. A total of 125 players aged between 15 and 18 years participated. Of these 125 players, 79 were followed for 1 season, 42 were followed for 2 seasons, and 4 were followed for 3 seasons, giving a total of 175 player-seasons. Body mass index was calculated as body mass (kilograms)/height^2 (meters), and players were categorized using age- and gender-specific BMI normative data provided by the Centers for Disease Control and Prevention: "underweight" (BMI for age $\leq$ 5th percentile), "normal weight" (BMI for age > 5th percentile to < 85th percentile), "at risk of overweight" (BMI for age 85th percentile to < 95th percentile), or "overweight" (BMI for age $\geq$ 95th percentile). It is important to note that the terms *overweight* and *at risk of overweight* refer to BMI and not body fat, which was not measured in this study. A high BMI in large muscular athletes, such as those who play American football, may not be owing to excessive fatness.

Based on the results of the previous study,[8] players were then further categorized as having minimal, low, moderate, or high risk of sustaining a noncontact ankle sprain according to their history of previous ankle sprains and their current BMIs (Table 1). Players categorized as low, moderate, or high risk (ie, a previous sprain and/or at risk of being overweight or overweight) were assigned to the stability pad intervention, whereas players categorized as minimal risk (ie, normal weight and no previous ankle sprain) were not assigned to the intervention.

The intervention consisted of single-limb balance training on a foam stability pad (Hygenic Corp, Akron, Ohio). Foam stability pads were used in preference to wooden ankle disks because they were less expensive, lighter, and therefore, more portable. The authors' previous clinical experience indicated that subjects favored balance training on foam pads versus wooden stability disks (wobble boards), and given that the study population was adolescent athletes, compliance was a concern. Subjects performed the balance training for 5 minutes on each leg, performed 5 days per week for 4 weeks in preseason and twice per week for 9 weeks during the season. All subjects in the intervention group performed the balance training on both legs. The pads were placed in the weight training room, and a designated balance training station was incorporated into the weight training routine. Compliance was recorded by the team's athletic trainer. Missed balance training sessions were made up before the next balance session.

An inversion ankle sprain was defined as an ankle injury with an inversion mechanism requiring the player to miss at least 1 game or practice. Injuries were graded as 1, 2, or 3 using the same criteria as that of Baumhauer et al.[2] A contact injury was defined as an injury that occurred when 2 or more players were engaged during the act of tackling, blocking, or pass protection and in which the external force causing the inversion moment at the ankle was primarily owing to the force applied by another player's body when the injured player's foot was fixed to the ground. All other injuries were classified as noncontact. Two athletic trainers observed, documented, and classified all injuries and recorded all relevant data. One trainer was responsible for each school. All missed games due to injury or other reason were recorded to provide an accurate measure of exposure for each athlete. Injury incidence was calculated as injuries per 1000 player exposures, with an exposure defined as a player's participation in a game or practice. Exposures for players who sustained contact ankle sprains were not included in analyses of risk factors for noncontact injuries, as these players could not be categorized as uninjured.

The incidence of noncontact inversion ankle sprains for the 3 seasons after the introduction of the intervention was compared with the incidence before the intervention using χ^2 analyses and the Fisher exact tests where appropriate based on cell sizes. The data before the intervention were previously reported for the varsity and junior varsity teams from 1 school followed for 3 seasons and 1 school followed for 1 season (2000-2002).[8] In the current study, only varsity teams were studied. These were the same 2 schools that were followed in the postintervention period. We thought that compliance with the intervention would be better in varsity players and that the team's athletic trainer would be better able to supervise the stability pad intervention when only 1 team was involved. Therefore, only the data for the varsity players from the previous study were used here for comparison. Because a player's risk category could change from season to season, based on changing BMI and/or sustaining an ankle sprain, each player who was followed for more than 1 season was counted separately for the purposes of risk categorization and subsequent calculation of injury incidence. There were 84 varsity football players in the preintervention period (Table 2), of whom 61 were followed for 1 season and 23 were followed for 2 seasons (107 player-seasons). Because only players in the low-, moderate-, and high-risk groups were placed on the intervention, injury incidence for these groups was compared with similarly categorized players from the preintervention period. The data for the minimal-risk players (normal weight and no previous ankle sprain) were not expected to be significantly different for the preintervention and postintervention periods because these players were not included in the stability pad training. Injury incidences are reported as injuries per 1000 exposures with 95% confidence intervals (CIs). Based on

TABLE 1
Risk Categories for Determining Which Players Were Placed on the Intervention

Risk Category	Description	Intervention Status
Minimal risk	No previous ankle sprain + normal weight	Not on intervention
Low risk	No previous ankle sprain + at risk for being overweight OR previous ankle sprain + normal weight	On intervention
Moderate risk	No previous ankle sprain + overweight OR previous ankle sprain + at risk for being overweight	On intervention
High risk	Previous ankle sprain + overweight	On intervention

TABLE 2
Preintervention Ankle Sprains Classified by Previous Ankle Sprain and BMI Grouping

	Preintervention: 107 Player-Seasons[a]					
	Previous Ankle Sprain			No Previous Ankle Sprain		
	Normal BMI	At Risk of Being Overweight	Overweight	Normal BMI	At Risk of Being Overweight	Overweight
Number of player-seasons	7	11	11	32	27	19
Number of ankle sprains	1	5	5	2	4	4
Contact	0	2	0	1	2	3
Noncontact	1	3	5	1	2	1
Exposures[b]						
Contact	497	656	491	2489	1960	1466
Noncontact	584	762	870	2492	1971	1305
Incidence						
Contact	0	3	0	0.4	1	2
Noncontact	1.7	3.9	5.7	0.4	1	0.8
95% confidence interval						
Contact		0.4-11.0		0.1-2.2	0.1-3.7	0.4-6.0
Noncontact	0.1-0.9	0.8-11.5	1.9-13.4	0.1-2.2	0.1-3.7	0.1-4.3

[a]There were 61 players for 1 season and 23 players for 2 seasons. A player-season is 1 player followed for 1 season. A player followed for 2 seasons counts as 2 player-seasons.

[b]Exposures listed under "contact" are the number of games and practices for all the players in that body mass index (BMI) group minus the exposures for any players who sustained noncontact injuries. Similarly, exposures listed under "noncontact" are the number of games and practices for all the players in that BMI group minus the exposures for any players who sustained contact injuries.

the prevalence of noncontact ankle sprains in "at-risk" players in the preintervention period (18%), it was estimated that a reduction in prevalence to 4% could be detected ($P < .05$, 80% power) with the same sample size as the preintervention period. Because a greater number of players were to be followed in the postintervention period, it was estimated that a reduction to 7% could be detected ($P < .05$, 80% power).

RESULTS

Risk Group Stratification

For the postintervention period, 47 of 175 player-seasons (27%) were categorized at minimal risk, 70 (40%) as low risk, 47 (27%) as moderate risk, and 11 (6%) as high risk (Table 3). For the preintervention period, these proportions were 32 of 107 (30%) for minimal risk, 39 (36%) for low risk, 30 (28%) for moderate risk, and 11 (10%) for high risk (Table 2).

Injury Prevalence

In the preintervention period, 21 of 84 players sustained inversion ankle sprains. Of the 21 sprains, 13 were noncontact injuries. Nine were grade 1 sprains, 3 were grade 2 sprains, and 1 was a grade 3 sprain. Nine of the 13 noncontact injuries were sustained by players who had sustained a previous injury (7 reinjured the same side, 1 injured the contralateral side, and 1 had previously injured both ankles). In the postintervention period, 20 of 125 players sustained inversion ankle sprains, of which 9 were noncontact injuries: 4 were grade 1, 3 were grade 2, and 2 were grade 3. Five of the 9 noncontact injuries were sustained by players who had sustained a previous injury (2 reinjured the same side, 1 injured the contralateral side, and 2 had previously injured both ankles). No player sustained more than 1 injury during the preintervention or postintervention periods of the study.

Over the 3 postintervention seasons, 128 of 175 player-seasons were assigned to the intervention. Twelve of these

TABLE 3
Postintervention Ankle Sprains Classified by Previous Ankle Sprain and BMI Grouping

	Postintervention: 175 Player-Seasons[a]					
	Previous Ankle Injury			No Previous Ankle Injury		
	Normal BMI	At Risk of Being Overweight	Overweight	Normal BMI	At Risk of Being Overweight	Overweight
Number of player-seasons (on intervention)	26 (21)	23 (22)	11 (10)	47 (0)	44 (39)	24 (24)
Number of ankle sprains	4	6	2	5	2	1
Contact	1	5[b]	1	2	2	0
Noncontact	3[c]	1	1	3	0	1
Exposures						
Contact	1990	1926	831	3573	3752	1934
Noncontact	2121	1589	822	3591	3619	2030
Incidence						
Contact	0.5	2.6	1.2	0.6	0.5	0
Noncontact	1.4	0.6	1.2	0.8	0	0.5
95% confidence interval						
Contact	0.1-2.8	0.8-6.0	0.1-6.7	0.1-2.0	0.1-1.9	
Noncontact	0.3-4.1	0.1-3.5	0.1-6.8	0.2-2.4		0.1-2.7

[a]There were 79 players for 1 season, 42 players for 2 seasons, and 4 players for 3 seasons.
[b]One contact ankle sprain occurred in a player who was classified as at risk of being overweight and had a previous sprain but who did not participate in the intervention.
[c]One noncontact ankle sprain occurred in a player with a previous sprain and a normal body mass index (BMI) who did not participate in the intervention.

players chose not to participate or did not comply with the intervention (10 low risk, 1 moderate risk, 1 high risk). Of these 12 players, 1 sustained a grade 3 noncontact inversion ankle sprain (he was in the low-risk group), and 1 player sustained a grade 1 contact injury (he was in the moderate-risk group). The 12 players who did not participate in the intervention and players who sustained a contact ankle sprain in either the preintervention or postintervention periods were not included in the analysis of the effect of the intervention on injury prevalence or incidence. All of the players who completed the intervention had a minimum of 34 of 38 balance training sessions (total: 20 preseason sessions and 18 regular season sessions, assuming no postseason play).

In the preintervention period, there was 1 noncontact ankle sprain in 32 player-seasons in the minimal-risk group (3% prevalence) and 12 noncontact ankle sprains in 68 player-seasons in the low-, moderate-, and high-risk groups (18% prevalence). For the postintervention period, there were 3 noncontact ankle sprains in 44 player-seasons in the minimal-risk group (7% prevalence) and 6 noncontact ankle sprains in 128 player-seasons in the low-, moderate-, and high-risk groups (5% prevalence). One of these 6 injuries occurred in a player who should have been on the intervention but chose not to. Injury prevalence for the players actually on the intervention was 5 noncontact injuries in 116 player-seasons (4% prevalence). The prevalence of noncontact inversion ankle sprains was significantly reduced (18% to 4%, $P < .01$) for the players identified as being at risk for injury (low-, moderate-, and high-risk groups) and who were on the intervention. Of the 9 postintervention noncontact sprains, 5 occurred in players with a previous injury, 1 at risk for being overweight, and 1 being overweight. The remaining 4 injuries occurred in 3 normal-weight players and 1 overweight player who had no previous injuries. Previous ankle sprains ($P = .48$) and BMI classification ($P = .31$) were not significant postintervention risk factors.

Effect of Intervention on Injury Incidence

Before the intervention, the incidence of noncontact inversion sprains was 0.4 injuries per 1000 exposures (95% CI, 0.1-2.2) for minimal-risk players, 1.2 (95% CI, 0.2-3.4) for low-risk players, 1.9 (95% CI, 0.5-4.9) for moderate-risk players, and 5.7 (95% CI, 1.9-13.4) for high-risk players. Postintervention injury incidence was 0.8 (95% CI, 0.2-2.4) for minimal-risk players and 0.4 (95% CI, 0.1-1.5), 0.6 (95% CI, 0.1-2.0), and 1.4 (95% CI, 0.1-7.6), respectively, for the low-, moderate-, and high-risk players who were on the intervention. The injury incidence for the players on the intervention (low, moderate, and high risk combined) was 0.5 (95% CI, 0.2-1.3), was significantly lower ($P < .01$) than the combined injury incidence for the low-, moderate-, and high-risk players before the intervention (2.2; 95% CI, 1.1-3.8). This represents an overall reduction in injury incidence of 77% (95% CI, 31%-92%), with a similar relative reduction for low-risk, moderate-risk, and high-risk groups (Figure 1). Preintervention injury incidence for the minimal-risk group (0.4; 95% CI, 0.1-2.2) (Table 2) was not different ($P = .87$) from the injury incidence for the minimal-risk group in the postintervention period (0.8; 95% CI, 0.2-2.4) (Table 3).

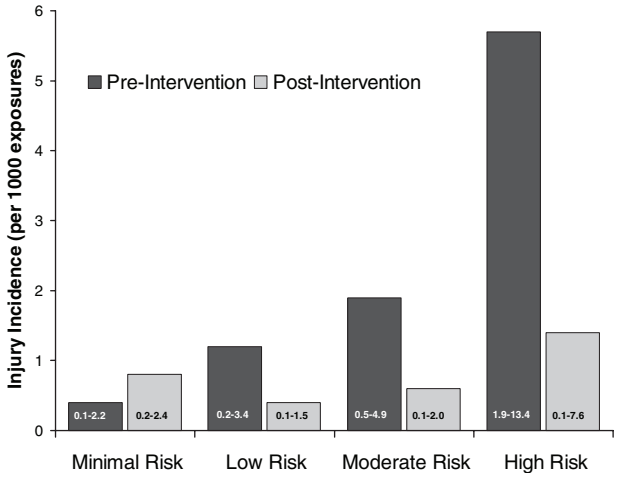

Figure 1. The incidence of noncontact inversion ankle sprains stratified according to the risk categories described in Table 1 (95% confidence intervals are given in the respective bars). The effect of previous ankle sprain and body mass index classification on preintervention risk (χ^2 linear trend $P < .01$) was eliminated by the intervention (postintervention χ^2 linear trend $P = .99$).

Effect of Brace and Tape Use

During the preintervention period, 7 players used ankle tape, 10 players used ankle braces, and 3 players used both. During the postintervention period, 12 players used ankle braces, 13 used ankle tape, and 9 used both. Ankle tape and braces were used primarily by players who had previous ankle sprains. Fifteen of 20 players (75%) using ankle tape or braces in the preintervention period and 27 of 34 players (79%) using ankle tape or braces in the postintervention period had previous ankle sprains. Tape or brace use in players with previous injuries did not affect subsequent injury incidence in the preintervention period (brace/tape users: 5.2, 95% CI, 1.9-11.4; nonusers: 2.8, 95% CI, 0.6-8.2; $P = .6$) or the postintervention period (brace/tape users: 2.0, 95% CI, 0.6-5.2; nonusers: 0.4, 95% CI, 0.1-2.2; $P = .2$). Sample sizes were insufficient to differentiate between brace or tape effects. In addition, the effects of brace and tape use on injury incidence are confounded by the fact that most brace and tape users had previous ankle injuries, which was in itself a risk factor for injury.

Effect of Playing Position

The preintervention incidence of noncontact ankle sprains was previously reported to be unaffected by playing position.[8] This was also apparent in the postintervention period ($P = .5$). Injuries per 1000 exposures were 0.4 (95% CI, 0.1-2.4) for receivers/defensive backs, 1.2 (95% CI, 0.3-3.6) for quarterbacks/running backs/linebackers, 0.6 (95% CI, 0.1-1.7) for linemen, and 0.6 (95% CI, 0.1-2.3) for players playing a combination of these positions. Given the limited number of injuries in the postintervention period, there was limited power to detect an effect of position. However, allied with the previous findings,[8] risk of noncontact ankle sprain does not seem to be affected by playing position, and this seems to be true even when other significant risk factors are eliminated.

DISCUSSION

The aim of this study was to test the effectiveness of a balance training intervention in reducing the incidence of noncontact inversion ankle sprains in high school football players who were identified as being at increased risk for injury. The intervention was based on previous studies showing that ankle disk training reduced the incidence of ankle sprains.[1,7,9,10] Compliance with the stability pad intervention used here was excellent (91%). The intervention was successful in reducing injury incidence by 77%, thereby eliminating the risk associated with a previous ankle sprain and/or a high BMI.

The results of this study are in agreement with previous studies showing reductions in ankle sprains after a balance training intervention.[1,7,9,10] Of note, these 4 previous studies did not discriminate between contact and noncontact ankle sprains. This distinction may be less of a concern in soccer,[7] volleyball,[1,9] and European handball[10] compared with American football, which is a more physical sport involving full body tackling. Only 1 of these studies randomized subjects into treatment and control groups[9] and showed that the injury reduction was limited to those players who had a previous ankle sprain. This supports an approach of targeting interventions to those players previously identified as being at increased risk for injury (previous ankle sprain is a known risk factor).

Although the results show a significant effect of the intervention, there are some limitations to these findings. (1) A limitation of this and other studies[1,7,10] is that the interventions were not randomized into treatment and control groups. (2) Confounding factors such as changes in training regimen between seasons; use of different size cleats, high-top versus low-top cleats; and differences in playing surfaces for road games were not controlled or specifically documented in this study. However, the same athletic trainers were in place with each school for the duration of the study, and no obvious changes occurred between seasons. (3) Because the use of ankle braces has been shown to reduce recurrent sprains,[5-7] the lack of control over ankle brace and tape use is an additional confounding factor. In the present study, the use of tape or braces was at the player's discretion. The type of brace and the correct fitting were not controlled. (4) Twelve players who should have been on the intervention chose not to participate. These players were excluded for analysis of the effect of the intervention on injury incidence. Alternatively, they could have been included on an intention-to-treat basis. Although this may be regarded as a limitation, it did not adversely affect the results. One of the 12 players who should have been on the intervention sustained a noncontact injury (incidence, 1.1 injuries per 1000 exposures). The postintervention injury incidence for players at risk, regardless of whether they were on the intervention, was

0.58 injuries per 1000 exposures, which is still significantly lower ($P < .01$) than 2.2 injuries per 1000 exposures for at-risk players before the intervention.

Although it was not within the scope of this study to examine possible mechanisms for the protective effect, the rationale was that stability pad training would improve proprioception and/or improve proximal control of body mass, thereby avoiding an inversion ankle injury. The increased risk associated with a high BMI and a previous ankle sprain was previously explained in biomechanical terms.[8] Ankle sprains can occur when the forces required for the change in momentum exceed the dynamic stability of the ankle joint. Players with a higher BMI will have to generate greater forces to change momentum at a given movement velocity. If these forces generate an inversion moment at the ankle, dynamic stability may be insufficient to stabilize the joint. In this manner, the combination of a high BMI and a previous ankle sprain (which likely decreases ankle stability) can have a compounding effect on risk of injury. Improved dynamic stability of the ankle joint and lower extremity, in addition to improved proximal control of body mass during dynamic movement, may be beneficial in injury prevention.

In conclusion, stability pad training was an easily implemented intervention that proved very effective in reducing the incidence of noncontact inversion ankle sprains in high school football players. Injury incidence was reduced by 77%, and the increased risk associated with a previous ankle sprain and a high BMI was effectively eliminated.

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