

Effectiveness of a home-based balance-training program in reducing sports-related injuries among healthy adolescents: a cluster randomized controlled trial

Carolyn A. Emery, J. David Cassidy, Terry P. Klassen, Rhonda J. Rosychuk, Brian H. Rowe

Abstract

Background: Sport is the leading cause of injury requiring medical attention among adolescents. We studied the effectiveness of a home-based balance-training program using a wobble board in improving static and dynamic balance and reducing sports-related injuries among healthy adolescents.

Methods: In this cluster randomized controlled trial, we randomly selected 10 of 15 high schools in Calgary to participate in the fall of 2001. We then recruited students from physical education classes and randomly assigned them, by school, to either the intervention ($n = 66$) or the control ($n = 61$) group. Students in the intervention group participated in a daily 6-week and then a weekly 6-month home-based balance-training program using a wobble board. Students at the control schools received testing only. The primary outcome measures were timed static and dynamic balance, 20-m shuttle run and vertical jump, which were measured at baseline and biweekly for 6 weeks. Self-reported injury data were collected over the 6-month follow-up period.

Results: At 6 weeks, improvements in static and dynamic balance were observed in the intervention group but not in the control group (difference in static balance 20.7 seconds, 95% confidence interval [CI] 10.8 to 30.6 seconds; difference in dynamic balance 2.3 seconds, 95% CI 0.7 to 4.0 seconds). There was evidence of a protective effect of balance training in over 6 months (relative risk of injury 0.2, 95% CI 0.05 to 0.88). The number needed to treat to avoid 1 injury over 6 months was 8 (95% CI 4 to 35).

Interpretation: Balance training using a wobble board is effective in improving static and dynamic balance and reducing sports-related injuries among healthy adolescents.

CMAJ 2005;172(6):749-54

teoarthritis later in life.⁶⁻⁸ In addition, each year 8% of adolescents drop out of sports activities because of injury.⁹ The reduction in physical activity resulting from sports-related injuries could have significant long-term effects on morbidity and mortality.^{10,11}

Proprioceptive balance training is used in rehabilitation following sports-related injuries and is becoming recognized as an important element in injury prevention in sports.¹²⁻¹⁹ Running, jumping or pivoting on one leg relies on a sense of joint position and muscular control for joint stability. There is evidence that static balance improves following proprioceptive balance training using a wobble board.²⁰⁻²³ However, most of these studies did not examine the effect of dynamic proprioceptive balance training, which may improve postural control in athletic situations and prevent some injuries.

There is evidence from randomized trials that multifaceted prevention programs, including proprioceptive balance training using a wobble board, are effective in reducing injuries to the lower extremities in specific sports.¹²⁻¹⁹ However, the programs in these trials were multifaceted (i.e., included warm-up, flexibility, jump training, strength training, rehabilitation and sport-specific technical components), and balance was not measured. The effectiveness of balance training alone on balance ability and prevention of injury remains unclear. Moreover, the use of these techniques in adolescents and non-elite athletes has not been studied.

The objectives of our study were to determine the effectiveness of a proprioceptive home-based balance-training program in improving static and dynamic balance in adolescents and to examine the effectiveness of this training program on reducing sports-related injury among adolescents.

Methods

We randomly recruited 10 of 15 high schools of the Calgary Board of Education to participate in the fall of 2001. Computer-generated random numbers were used to recruit schools and students and to allocate the schools to the intervention or control group. We randomly selected 2 males and 2 females from physical education program rosters in each of grades 10 to 12. If a subject declined participation or dropped out after the baseline assessment but before a follow-up assessment, we recruited another stu-

Adolescents commonly participate in sports.^{1,2} In a survey of adolescents in Alberta, 59% reported that they took part in sports more than 5 hours per week (unpublished data). In North America, sport is the leading cause of injury requiring medical attention and visits to an emergency department among adolescents.^{3,4} In Alberta 26% of youths aged 15-19 years in a survey reported sustaining a sports-related injury requiring medical attention.⁵ The impact may be lifelong, as there is evidence that knee and ankle injuries may result in an increased risk of os-

dent of the same sex from the same school and grade. The study was blinded in that we randomly allocated schools to the intervention or control group following initial subject recruitment. All assessments were performed by a physiotherapist.

We included subjects if they were between the ages of 14 and 19 years, regularly attended classes and participated in physical education classes. We excluded subjects if they had a history of a musculoskeletal injury in the 6 weeks before recruitment, a previous history of a serious musculoskeletal disorder (e.g., fracture, rheumatologic disease, systemic disease or surgery) or an important medical condition (e.g., hypertension, or recurrent fainting or dizzy spells).

Each subject was asked to complete a baseline questionnaire, which included questions about previous history of injuries and participation in sports. At the initial assessment, the physiotherapist measured each participant's height and weight. Each subject completed, with their eyes closed, a timed static unipedal balance test on the gym floor and a timed dynamic unipedal balance test on an Airex Balance Pad (Fitter International Inc., Calgary). We have previously shown adequate test-retest reliability for these 2 measurements (intraclass correlation 0.7 and 0.5 respectively).²⁴ During these tests, time was recorded when the subject's balance

was lost or eyes opened, or when the maximum time allowed for each trial (180 seconds) was reached. The baseline assessment also included a vertical jump test²⁵ to examine functional strength and the Canadian version of the 20-m shuttle run to test endurance.²⁶

A physiotherapist taught each participant in the intervention group a progressive, home-based, proprioceptive balance-training program to be used daily for 6 weeks and then weekly for maintenance for the remainder of the 6-month study period. A 16-inch (40-cm) wobble board (Fitter International Inc.) was provided. At the 2- and 4-week follow-up assessments the program was reviewed and progressed. Progression at 2 weeks included bipedal to unipedal exercise progression and increased duration of eye-closed elements of the program. At 4 weeks progression involved wobble board adjustment to level 2, which increased the amount of wobble board instability. Core stabilization, including isometric contraction of abdominal and gluteal muscles was incorporated into the program. Each daily session was expected to last about 20 minutes, and self-reported compliance with the training program was assessed by a daily record sheet and weekly telephone calls over the 6-week training period. Each subject was retested (i.e., balance, vertical jump and shuttle run tests) biweekly over 6 weeks by the physiotherapist. For the

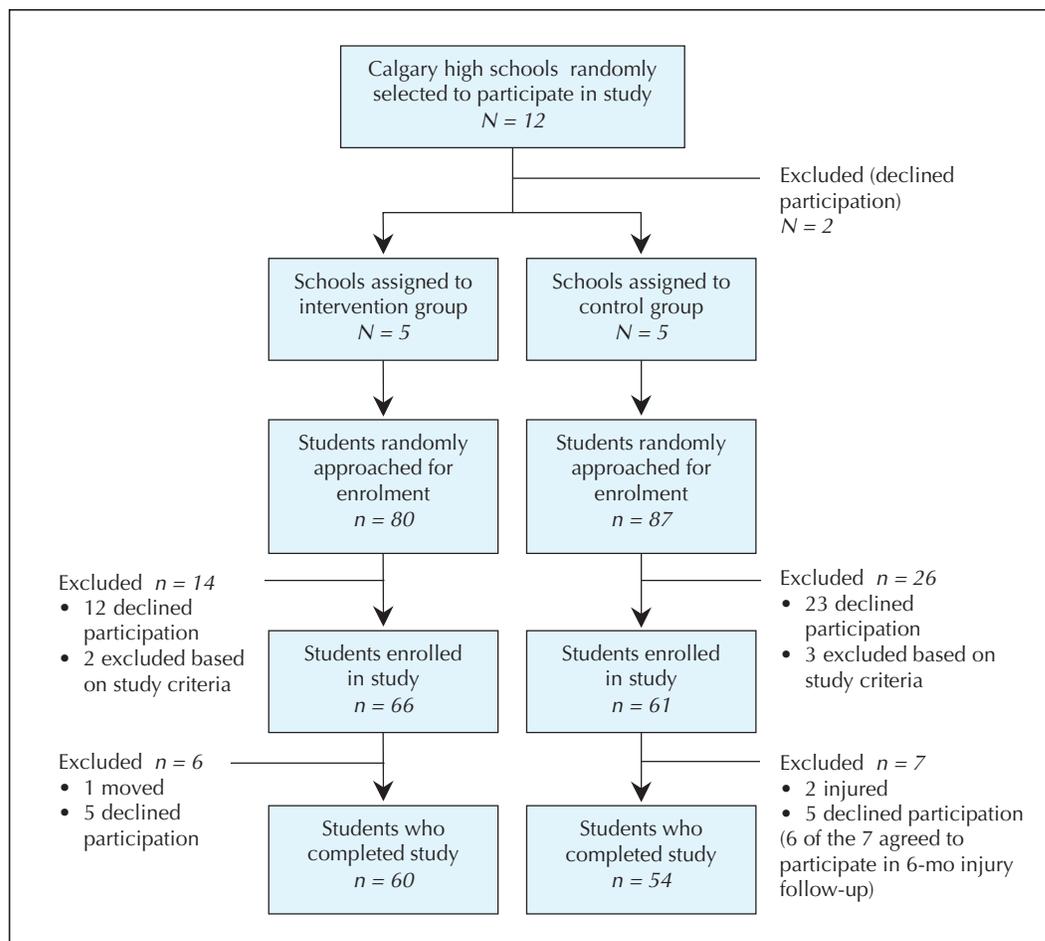


Fig. 1: Recruitment and allocation of schools and students to study groups. Subjects in the intervention group underwent a 6-week home-based proprioceptive balance-training program using a wobble board. All of the subjects underwent timed balance tests at baseline and at 2, 4 and 6 weeks. They were also asked to report sports-related injuries over the 6-month study period.

6-month follow-up period, each subject was asked to complete a sport participation record sheet and an injury report form as required. An athletic injury was defined as any injury occurring during a sporting activity that required medical attention (i.e., visit to an emergency department or physician's office, chiropractic, physiotherapy or athletic therapy) or resulted in the loss of at least 1 day of sporting activity, or both. Injury report forms included a section to be completed by any attending medical professional. The physiotherapist made biweekly telephone calls to all study participants during the 6-month follow-up period to ensure that all eligible injuries were reported.

The primary outcome measures included the change from baseline to 6-week follow-up in the maximum time that balance was maintained during the static and dynamic tests over 6 trials, 3 for each leg. Measurements for both legs were pooled because there is no evidence that balance differs by side.²⁴ The primary injury outcome measure included all self-reported sports-related injuries and ankle sprain injuries.

Because of the cluster randomization design of the study, to calculate the sample size we had to take into account the possible similarity in the response of individuals within each cluster.²⁴ We assumed an intraclass correlation of $\rho = 0.01$ based on a comparison with the mean ρ found by Murray and associates²⁷ of $\rho = 0.006$ in examining adolescent smoking behaviour. We also adjusted for a potential drop-out and noncompliance rate in the intervention group and a contamination rate in the control group ($R_0 = 0.10$). On the basis of the primary outcome variable static balance, this trial was powered to detect an effect size of $d = \delta/\sigma = 0.8$ (where $\delta = \mu_1 - \mu_2 = \text{mean [intervention group]} - \text{mean [control group]} = 9$ seconds; and $\sigma = 11$ seconds = the estimated common standard deviation of the timed balance test measurement in the control and intervention group), assuming a type I error ($\alpha = 0.05$) and type II error ($\beta = 0.10$).

We report descriptive statistics for baseline characteristics. Baseline variables were compared between the 2 groups. We calculated the mean difference in static and dynamic balance test results from baseline to the 6-week follow-up for the intervention and control groups and compared them using both independent and cluster-adjusted *t* tests.²⁸ Where the assumptions of normality and equal variance were not met, the data were logarithmically transformed.²⁹ In this case the measure of central tendency used was a geometric mean, which was estimated by back-transformation from the mean of the log-transformed data. Our analyses were based on the intention-to-treat principal. We used multivariable mixed-effects regression analysis (i.e., allowing random effects for cluster) to examine further the effectiveness of the training program in improving both static and dynamic balance test results, controlling for other baseline covariates.²⁸ To determine our final model, we eliminated covariates through a stepwise process, with α at 0.05.

We compared injury incidence rates in the 2 study groups by calculating the relative risk. Given the small number of injuries reported in 6 months, the intraclass correlation coefficient was calculated on the basis of the history of injuries reported in the year before study enrolment. A cluster-adjusted χ^2 analysis was not warranted, because the estimated intraclass correlation coefficient was negative and hence given the value 0.²⁸ This indicates that cluster randomization was not expected to affect the outcome related to comparison of injury rates. Stratified analysis based on previous injury was also examined using Fisher's exact methods.²⁹ We used logistic regression to examine the effectiveness of the training program in reducing injury, while controlling for other baseline covariates.

Results

The selection and allocation of high schools to the study groups and the recruitment of students is outlined in Fig. 1. The rate of consent to participate was high (76%) and the dropout rate low (10%). The baseline characteristics did not differ significantly between the 2 groups (Table 1). A ceiling effect was demonstrated on the static balance test: 4 students reached the maximum time allowed (180 seconds) at baseline, 10 reached it at 2 weeks, 10 reached it at 4 weeks, and 14 reached it at 6 weeks. These subjects were excluded from the analyses involving static test measurements.

Improvements in static and dynamic balance during the follow-up period were greater in the intervention group than in the control group (Fig. 2 and Fig. 3). The results of the individual level and cluster-adjusted analyses examining static and dynamic balance favoured the intervention group (Table 2). After adjustment for covariates, mixed-effects linear regression analyses reproduced the main findings for static and dynamic balance (Table 3). At 6 weeks, improvements in static and dynamic balance were observed in the intervention group but not in the control group (mean difference in static balance from baseline 20.7 seconds, 95% confidence interval [CI] 10.8 to 30.5 seconds; mean difference in dynamic balance from baseline 2.3 seconds, 95% CI 0.7 to 4.0 seconds).

Table 1: Baseline characteristics of high school students in intervention (balance training) and control groups

Characteristic	Group; mean (95% CI)*	
	Training group <i>n</i> = 60	Control group† <i>n</i> = 60
Age, yr	15.9 (15.6–16.1)	15.8 (15.5–16.0)
Male sex, %	50	50
Previous injury, % of students		
Lower extremity	25 (15–38)	15 (7–27)
All	40 (28–54)	32 (20–45)
Height, m	1.71 (1.70–1.74)	1.69 (1.67–1.71)
Weight, kg	64.8 (61.4–68.3)	65.4 (62.1–68.7)
Body mass index, kg/m ²	21.9 (20.8–23.1)	23.1 (21.9–24.3)
Hours spent per wk participating in sports during 6 wk before study	9.4 (7.6–11.3)	7.8 (6.2–9.5)
Vertical jump, cm	40.4 (37.6–43.1)	37.2 (34.6–39.8)
Predicted maximum oxygen consumption,‡ mL/kg·min	34.9 (32.6–37.2)	34.4 (32.4–36.4)
Balance, geometric mean, s		
Static	25.9 (21.1–31.7)§	33.1 (26.8–40.8)¶
Dynamic	5.5 (4.9–6.2)	5.9 (5.3–6.7)

Note: CI = confidence interval.

*Unless stated otherwise.

†Includes 6 students who did not complete 6-week follow-up measurements but who agreed to participate in the 6-mo injury follow-up.

‡Based on 20-m shuttle run, measured as mL/kg·min.

§One subject reached maximum allowed time (180 s).

¶Three subjects reached maximum allowed time.

Compliance with balance training sessions had an effect on the change in static balance: the observed change among students in the intervention group who reported fewer than 18 sessions over 6 weeks was 6.1 seconds (95% CI -8.4 to 20.7), as compared with 25.8 seconds (95% CI 16.4 to 35.1) among those who reported 18 or more sessions. Compliance did not have a significant effect on change in dynamic balance.

Twelve (5 female and 7 male) subjects reported athletic injuries over the 6-month observation period: 2 were in the intervention group, and 10 were in the control group (Table 4). The median time lost from a sporting activity because of an injury was 13 (range 7–28) days. The median time to injury occurrence from the start of the study was 13 (range 2–24) weeks. The injuries reported occurred while the students were playing basketball (4/12), soccer (3/12), football (2/12), hockey (2/12) and volleyball (1/12). The relative risk of all injury was 0.20 (95% CI 0.05 to 0.88), and of ankle sprain 0.14 (95% CI 0.18 to 1.13). Compliance in collecting prospective sports participation data was low (43.3%), which resulted in insufficient data to estimate incidence density (i.e., number of injuries per 1000 participation hours).

There was an important difference in the incidence rate of self-reported injury (number of injuries per 100 adolescents) between the intervention and control groups: 3 (95% CI 0 to 12) versus 17 (95% CI 8 to 29) respectively, for a difference of 14 (95% CI 3 to 24). The number needed to treat to avoid 1 injury over 6 months was 8 (95% CI 5 to 35). The training program was more effective among subjects who reported an injury in the previous year (relative risk [RR] 0.13, 95% CI 0.02 to 1.0) than among

those who reported no previous injury (RR 0.28, 95% CI 0.03 to 2.43).

Multiple logistic regression analysis reproduced the main finding that the training program was effective in preventing injury, after adjustment for other covariates in the analysis. The estimated odds ratio (OR) associated with injury in the intervention group compared with injury in the control group was 0.15 (95% CI 0.03 to 0.72). The OR associated with previous injury regardless of study group was 3.51 (95% CI 0.98 to 12.49).

Interpretation

We found clinically important improvements in static and dynamic balance as well as a reduction in self-reported athletic injuries over 6 months among high school students participating in a regular physical education program who used a simple 6-week home-based proprioceptive balance-training program.

The improvement in static balance following balance training with a wobble board is consistent with findings of other studies.^{17,21–23} In addition, we found that the improvement was greater with increased reported compliance. Despite the small number of clusters and wide confidence intervals around the estimates for injury incidence rates, there was a significant and clinically important difference in injury rate between the intervention and control groups. The relative risk of injury found in our study (RR 0.20, 95% CI 0.05 to 0.88) is consistent with the finding in the only other randomized controlled trial examining a similar prevention program for adolescents (RR 0.17, 95% CI 0.09 to 0.32) and in studies involving adults (RR 0.06–0.51).^{12–19} In our study, we also found evidence that previous injury

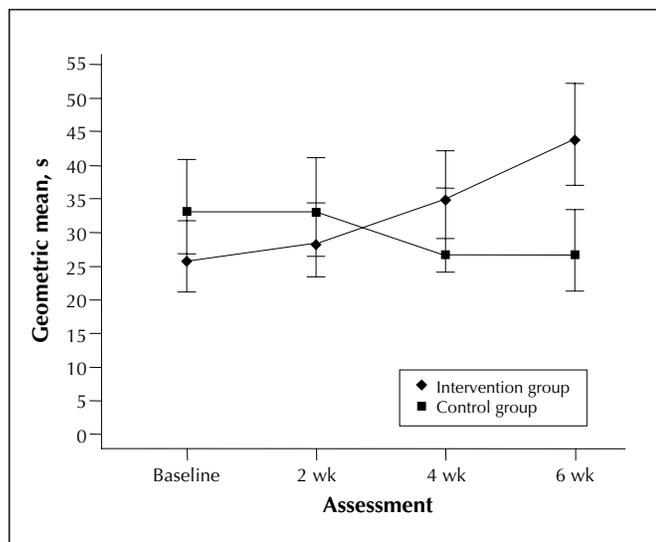


Fig. 2: Geometric means for timed static balance test. Each subject was asked to stand on one leg, with eyes closed, on the gym floor. Time was recorded when the subject's balance was lost, eyes opened, or the maximum allowable time (180 seconds) was reached.

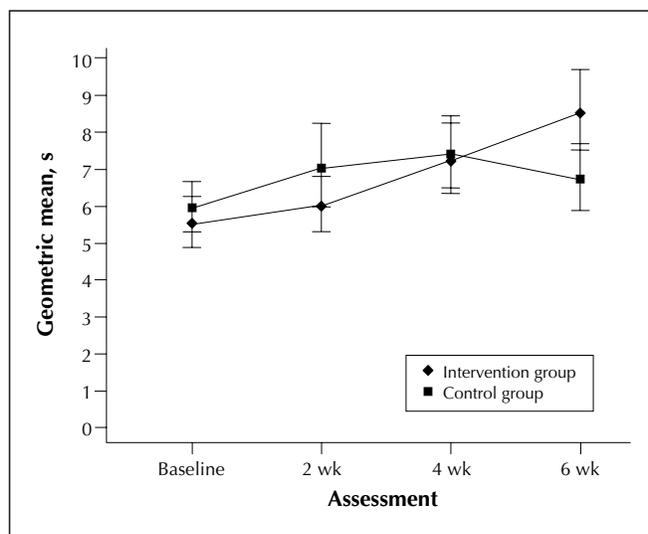


Fig. 3: Geometric means for timed dynamic balance test. Each subject was asked to stand on one leg, with eyes closed, on a balance pad. Time was recorded in the same manner as with the static test.

may be associated with future injury, independent of study group (OR 3.51, 95% CI 0.98 to 12.49), which is consistent with previously reported findings.¹²

Our study has limitations. Compliance in collecting prospective sports participation data was poor, probably because of the time intensity to report daily sports participation. Although some minor injuries may have been missed through self-reporting, the likelihood of this would not differ between the 2 groups, since biweekly follow-up by a physiotherapist was identical for both groups. Second, the moderate reliability and small inter-subject variability associated with the dynamic balance test could lead to an increased similarity between the study groups for this study variable. The resultant nondifferential measurement bias may have diluted the association found between the study groups on change in dynamic balance. Third, the ceiling effect of the static balance test led to the inability to examine changes in balance among subjects who reached the maximum time allowed (180 seconds) for this test. Notwithstanding these limitations, our study has many strengths. The effectiveness of the training program is valid and cannot be accounted for by differences in baseline characteristics between the 2 groups. A cluster randomized controlled trial with random recruitment of schools and subjects, and comprehensive primary and secondary end points, reduces the biases associated with the results and increases the generalizability of the study results. The high

rate of consent to participate and the low dropout rate limited potential selection bias.

A 6-week home-based proprioceptive balance-training program is effective in improving static and dynamic balance in healthy adolescents. The program was also effective in preventing all self-reported athletic injury over 6 months, and there was evidence that it may also reduce the risk of ankle sprain. The majority of injuries reported in our study were to the lower extremity and occurred while students were playing basketball, volleyball, soccer and hockey. All of these sports involve a high degree of pivoting or change of direction as well as rapid acceleration and deceleration manoeuvres. Future research should focus on the effectiveness of balance training in preventing injuries to the lower extremities during these sporting activities.

This article has been peer reviewed.

From the Sport Medicine Centre, Faculty of Kinesiology, University of Calgary, Calgary, Alta. (Emery); the Division of Outcomes and Population Health, Toronto Western Research Institute, and the Department of Public Health Sciences, Faculty of Medicine, University of Toronto, Toronto, Ont. (Cassidy); and the Department of Pediatrics (Klassen, Rosychuk), the Department of Public Health Sciences (Klassen, Rowe) and the Division of Emergency Medicine, Faculty of Medicine, University of Alberta, all in Edmonton, AB.

Table 2: Difference in balance measurements between intervention and control groups based on change from baseline to follow-up test results (individual and cluster-adjusted 2-sample *t*-test analysis)

Measurement interval	Difference between groups (95% CI), s	Cluster-adjusted <i>t</i> test (intracluster correlation coefficient)
Static balance		
Baseline–2 wk	–2.4 (–4.2 to 6.5)*	NA (0)†
2 wk–4 wk	–14.9 (–24.1 to 5.8)*	NA (0)†
4 wk–6 wk	–11.9 (–19.3 to –4.4)*	NA (0)†
Baseline–6 wk	–26.4 (–41.5 to –11.4)	<i>t</i> ₀ = 4.05; <i>p</i> < 0.004 (0.0358)
Dynamic balance		
Baseline–2 wk	1.5 (–2.0 to 5.1)	<i>t</i> ₀ = –0.997; <i>p</i> = 0.35 (0.0873)
2 wk–4 wk	–1.9 (–5.7 to 2.0)	<i>t</i> ₀ = 1.118; <i>p</i> = 0.3 (0.1007)
4 wk–6 wk	–2.0 (–3.8 to –0.2)	<i>t</i> ₀ = 2.595; <i>p</i> = 0.03 (0.0095)
Baseline–6 wk	–2.2 (–5.2 to 0.9)	<i>t</i> ₀ = 1.647; <i>p</i> = 0.14 (0.1089)

*95% CI not adjusted for cluster randomization if intracluster correlation coefficient equal to 0.
†Negative values of intracluster correlation coefficient set equal to 0.

Table 3: Predicted difference in static and dynamic balance between baseline and 6-wk follow-up (mixed-effects linear regression models)

Variable	Coefficient	95% CI	<i>p</i> value
Static balance			
Intercept	–21.1	–42.1 to –0.1	0.049
Group*	20.7	10.8 to 30.6	< 0.0005
Balance at baseline†	–30.2	–41.5 to –18.9	< 0.0005
Maximum oxygen consumption‡	0.8	0.2 to 1.4	0.014
Dynamic balance			
Intercept	1.9	0.6 to 3.2	0.004
Group*	2.3	0.7 to 4.0	0.007
Balance at baseline§	3.0	–4.9 to –1.0	0.004

*Control = 0, intervention = 1.

†Based on static balance test maximum at baseline, where < 40 s = 0 and ≥ 40 s = 1 (≥ 40 s defines upper quartile).

‡Consumption at baseline, measured as mL/kg·min.

§Based on dynamic balance test maximum at baseline, where < 8 s = 0 and ≥ 8 s = 1 (≥ 8 s defines upper quartile).

Table 4: Self-reported sports-related injuries requiring medical attention or resulting in loss of at least 1 day from sporting activity

Group	No. and type of injury
Intervention	1 ankle sprain 1 metatarsal fracture
Control	7 ankle sprains 1 metacarpal fracture 1 shoulder strain 1 low-back strain

Competing interests: None declared.

Contributors: All of the authors contributed substantially to the conception and design of the study and to the analysis and interpretation of the data, revised the article critically for important intellectual content and gave final approval of the version to be published.

Acknowledgements: We acknowledge the Calgary Board of Education high school principals and physical education teachers, without whose support this research would not have been possible. We are especially grateful to the many students who consented to participate in this study.

We acknowledge the financial support of the Department of Pediatrics, University of Alberta. We thank Fitter International Inc. for providing the wobble boards and Airex Balance Pads at a substantially reduced cost. Carolyn Emery was supported by the Canadian Institutes of Health Research (CIHR) in partnership with the Physiotherapy Foundation of Canada, the Alberta Heritage Foundation for Medical Research (AHFMR), the CIHR Institute of Musculoskeletal Health and Arthritis, Bone and Joint Health Training Program, and the Walter Johns Graduate Scholarship Fund, University of Alberta. David Cassidy was supported by AHFMR as a Health Scholar. Rhonda Rosychuk is supported by the AHFMR as a Population Health Investigator, and Brian Rowe is supported by the CIHR as a Canada Research Chair.

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Correspondence to: Carolyn A. Emery, Sport Medicine Centre, Faculty of Kinesiology, University of Calgary, 2500 University Dr. NW, Calgary AB T2N 4E4; fax 403 220-9489; caemery@ucalgary.ca