A Prevention Strategy to Reduce the Incidence of Injury in High School Basketball: A Cluster Randomized Controlled Trial

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Objective: To examine the effectiveness of a sport-specific balance training program in reducing injury in adolescent basketball.

Design: Cluster randomized controlled trial.

Setting: Twenty-five high schools in Calgary and surrounding area.

Subjects: Nine hundred and twenty high school basketball players (ages 12–18).

Intervention: Subjects were randomly allocated by school to the control (n = 426) and training group (n = 494). Both groups were taught a standardized warm-up program. The training group was also taught an additional warm-up component and a home-based balance training program using a wobble board.

Main Outcome Measures: All injuries occurring during basketball that required medical attention and/or caused a player to be removed from that current session and/or miss a subsequent session were then recorded and assessed by a team therapist who was blinded to training group allocation.

Results: A basketball-specific balance training program was protective of acute-onset injuries in high school basketball [RR = 0.71 (95% CI; 0.5–0.99)]. The protective effect found with respect to all injury [RR = 0.8 (95% CI; 0.57–1.11)], lower-extremity injury [RR = 0.83 (95% CI; 0.57–1.19)], and ankle sprain injury [RR = 0.71 (95% CI; 0.45–1.13)] were not statistically significant. Self-reported compliance to the intended home-based training program was poor (298/494 or 60.3%).

Conclusions: A basketball-specific balance training program was effective in reducing acute-onset injuries in high school basketball. There was also a clinically relevant trend found with respect to the reduction of all, lower-extremity, and ankle sprain injury. Future research should include further development of neuromuscular prevention strategies in addition to further evaluation of methods to increase compliance to an injury-prevention training program in adolescents.

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There are significant health and wellness benefits of physical activity and sport. However, sport and physical activity is not without risk. Sport and recreation injuries are a significant health problem in Canada. Although most sport injuries are not life threatening, the occurrence of sport injury can result in pain, disability, and/or dysfunction in the short and long term. Injuries are a leading reason people stop participating in physical activity.[1] It is estimated that 8% of adolescents drop out of sport and recreational activities yearly as a result of injury.[2] There is evidence that sports are the leading cause of injury requiring medical attention and emergency department admissions in Canadian adolescents.[3–6] Furthermore, it is estimated that sport injuries account for 50% of all injuries to adolescents.[7]

There is epidemiologic evidence that level of physical fitness is a significant predictor of multiple-cause mortality and morbidity[8–11] and that physical activity patterns early in life predict those in later life.[12,13] The prospect of injury or incomplete recovery from injury affects the ability to participate in sport and recreational activities that would be beneficial to health. This is a serious concern given the US Surgeon General's suggestion that "overweight and obesity may soon cause as much preventable disease and death as cigarette smoking."[14] Injuries have also been documented to be a leading cause of the development of osteoarthritis in later life. Studies have shown that knee and ankle injuries, specifically, result in an increased risk of early development of osteoarthritis.[15–23] There is evidence that 12–20 years post knee injury, including meniscus and/or anterior cruciate ligament injuries, more than 50% will have knee osteoarthritis in comparison with 5% in the uninjured population.[18] There is a significant public health cost associated with sport injuries, osteoarthritis, and other diseases associated with decreased levels of physical activity.[24]

Basketball is both the top sport for participation and the top injury-producing sport in adolescents in Alberta.[25] The participation rate is reportedly 25 participants per 100 adolescents per year. Injuries in basketball accounted for greater than 12% of all sport injuries.[25] In a systematic review of the literature, Harmer[26] reports injury rates in high school basketball, ranging from 28 to 86 injuries per 100 players per season in studies in high school basketball where injury data were collected prospectively. Differences between studies are related to differences in injury definitions. A prospective study examining injury rates in high school basketball players (ages 14–18) in Texas reported injury rates of 3.6 and 3.2 injuries per 1000 player hours for females and males, respectively.[27] Ankle and knee are consistently the 2 most common areas for injury in high school basketball, with lower-extremity injuries accounting for more than 65% of all injuries.[26]

Currently, there is no standard of care for evidence-based injury-prevention strategies in youth sport. Primarily in elite athlete populations, balance training in conjunction with other preseason training strategies reduces the incidence of injury between 38% and 87% in sports such as European handball, soccer, basketball, and volleyball.[28–37] Emery et al[38] have further demonstrated in a cluster randomized controlled trial (RCT) that a balance training program alone, using a wobble board, is effective in improving balance ability and reducing injury in healthy adolescents by 80% (95% CI; 12%–95%). The objective of this study was to examine the effectiveness of a balance training program in reducing injury in high school basketball. The authors hypothesized that the training program would be effective in reducing injury in high school basketball.

METHODS

Design

This was a cluster RCT. Randomization by individual was not practical in this study because random assignment of adolescents within the same school setting would likely result in high rates of contamination.[39–41] In addition, because a preseason training program is often offered at a team level, cluster randomization had advantages in terms of external validity of the trial results.[41]

Subjects

The sampling frame consisted of 40 Calgary and area high schools. Random selection of schools was done by computer generation of random numbers. Ranking of these numbers determined the order in which schools were approached for recruitment. Prior to recruiting students from the basketball teams consent was obtained from school principals followed by the Physical Education directors and basketball coaches. The participating schools were randomized by school to each of the study groups following subject recruitment to ensure allocation concealment.

Inclusion criteria were adolescents who were enrolled in a high school in Calgary and surrounding area and who were a member of their respective interscholastic basketball team (junior/senior, male/female). Exclusion criteria for the study included an injury within 6 weeks that prevented full participation in basketball at the start of the basketball season, a history of systemic disease (ie, cancer, arthritis, heart disease), or neurologic disorder (ie, head injury, cerebral palsy). Parental consent was required to participate in the study for all participants younger than 18 years of age. Ethics approval was received from the Office of Biomedical Ethics at the University of Calgary and the Ethics Review Committee of the Calgary Public, Calgary Catholic, Foothills, Rockyview, and Christ the Redeemer School Boards.

Procedures

Each adolescent was asked to complete a baseline medical questionnaire and informed consent form at the time of initial assessment. This assessment was conducted by a team therapist (physiotherapist or Certified Athletic Therapist). The team therapist was blinded to training group allocation. The initial assessment included measurements of height, weight, and body mass index (kg/m^2). The subject also demonstrated leg dominance by kicking a soccer ball.

Each subject completed a timed, dynamic, eyes-closed, unipedal balance test on an Airex Balance Pad.[42] The outcome measurement of interest was the maximum time achieved in 3 trials on each leg. This measurement was previously examined and found to be reliable in adolescents.[42] The baseline assessment also included 2 additional measurements: a 20 meter shuttle run[43–45] and a vertical jump test.[46,47] The outcome measurements of interest were predicted maximal oxygen uptake (VO_2max in mL/kg per minute) based on the number of shuttles completed in the shuttle run and maximum height achieved in 3 vertical jump trials.

Injury surveillance and participation exposure data were collected using an injury surveillance system adapted for high school basketball from the Canadian Intercollegiate Sports Injury Registry (CISIR).[48] The adapted CISIR was previously validated in both adolescent soccer and hockey, where there is not a dedicated team physician or a pre-season medical examination completed, as for adolescent basketball.[49,50] In addition to measuring the incidence and circumstances surrounding injury, it also measures daily athlete participation and time missed from participation.

Each team was assigned a student team manager and team therapist. The team therapist was present for 1 session each week. The team manager, who was present at every team session, was asked to record the participation of each player on a Weekly Exposure Sheet (WES) for every game and practice. Players were described as being "Full" or "Partial" (<75% of full session time) participants in each session. However, if a player missed a session because of a basketball-related injury, illness, or other reason, they were indicated as having 0 participation. Partial participation hours were recorded as ½ of the full session hours. In the event of a basketball injury, the player was given an injury identification number (IID) that was also included on the Injury Report Form (IRF) and therapist assessment form.

Detailed information related to the circumstance, mechanism of injury, and diagnosis was documented initially on an IRF by the designated team manager if the therapist was not present. The therapist interviewed and examined any player who sustained an injury occurring during basketball resulting in medical attention beyond the team therapist assessment and/or the inability to complete the current session and/or participate in a subsequent basketball session (game or practice). Detailed information related to the circumstance, mechanism of injury, and diagnosis was further documented.

Any player with an injury requiring time loss from participation had the opportunity for follow up with a sports medicine physician at the University of Calgary or they could follow up with a family physician. The physician was asked to complete a diagnosis/treatment plan form.

The study period was 1 year. The basketball season was 18 weeks long (November 2004–March 2005). Telephone follow up continued until November 2005 for all injuries sustained that had not previously resolved to allow full return to sport.

A warm-up routine was taught to all of the coaches and teams by an independent study physiotherapist or Certified Athletic Therapist who was not the team therapist. The 10 minute warm-up routine included aerobic, static stretch, and dynamic stretch components. This was considered the "current standard of practice" for a high school basketball warm-up routine. In addition, teams in the training group received an additional 5 minute sport-specific balance training warm-up component for practice sessions and a 20 minute home exercise program using a wobble board. Each training team warm-up session was expected to be completed in a team setting prior to each basketball practice (ie, approximately 5 times per week). This was pretested at 2 high school basketball camps at the University of Calgary in the summer of 2004. Each participant in the intervention group was provided with a 16 inch diameter wobble board for their use at home. The study coordinator reviewed the progression of the program at 2 and 4 weeks with participating teams. Self-reported compliance journals were provided to record adherence to the wobble board training home program.

Sample Size

In adolescent basketball the proportion of players expected to be injured was 30%.[25] The predicted intracluster correlation (P = 0.006) was based on pilot RCT data examining sport injury and other adolescent behaviors.[36,51] We also adjusted for a potential dropout/noncompliance rate in the intervention group based on a previous pilot RCT (R_o = 0.05).[36] Assuming a Type I error (α = 0.05) and Type II error (β = 0.10), a total of 960 subjects were required to detect a relative risk reduction of 33%.

Statistical Analysis

Stata (Version 9.0) was used for all statistical analyses.[52] Baseline variables were compared across the study groups using 95% confidence intervals based on a generalized regression model with the variable of interest as the outcome variable (linear regression for continuous variables and logistic regression for binary variables) and the treatment designation variable as the only predictor variable. The regression was adjusted for clustering by team. Injury rates (number of injuries per 1000 player hours) and 95% confidence intervals were calculated using a Poisson regression model, with player hours included as an offset and adjustment for clustering by team. A multivariate Poisson regression analysis, which uses the individual as the unit of analysis and adjusts for covariates (ie, gender, age, previous injury, endurance, strength, balance ability, leg dominance) and clustering effects by team in the estimation of variability, was done to estimate the relative risk of injury in the training group compared with the control group. Two-way interactions were examined for evidence of intervention effect modification. Relative risk of acute-onset injury, lower-extremity injury, and ankle sprain injury was also estimated using the same methods.

RESULTS

The target study population consisted of all high school basketball teams in 40 schools. Fifteen school principals and/or physical education directors declined participation. Twenty-five schools (N = 89 teams) enrolled in the study. Thirteen schools were randomly allocated to the training group (N = 48 teams), and 12 schools (N = 41 teams) were allocated to the control group following recruitment of subjects to assure allocation concealment. One training group team dropped out of the study based on a coach decision. The study sample included 920 male and female basketball players ages 12–18 (grades 9–12). Selection and allocation of subjects are summarized in Figure 1. There were no clinically relevant differences between training groups based on baseline characteristics (Table 1).

There were a total of 271 injuries: 141 in the control group (n = 426) and 130 in the training group (n = 494). The injury rate in the control group was 33.1 injuries per 100 participants per season (95% CI; 28.64–37.79); in the training group it was 26.32 injuries per 100 participants per season (95% CI; 22.48–30.43). Injury rates by gender based on overall injury, acute-onset injury, lower-extremity injury, and ankle sprain injury are summarized in Figures 2–5.

The exposure in hours for the control group was 34,955 (n = 426); for the intervention group it was 39,369 (n = 494). Some weekly exposure (WES) data were missing for 173 of 920 players, or 18.8% (95% CI; 16.3–21.5). This proportion did not differ for the training group [18.2% (95% CI; 14.9–21.9)] and the control group [19.5% (95% CI; 15.8–23.6)]. Of all 88 teams, 70 returned complete exposure data for all participating players. Exposure data were imputed for missing values for individuals based on mean exposure hours reported by age group and gender when weekly data were missing for an entire team and based on mean exposure hours for a given team when weekly data were missing for individuals only. All Injury Report Forms were then cross-referenced to account for individual time loss related to basketball injuries reported.

Comparisons of injury rates (number of injuries per 1000 player hours) by injury type based on an intent to treat Poisson regression analysis are summarized in Table 2. Relative risks are summarized with 95% confidence intervals based on a cluster-adjusted Poisson regression analysis. This analysis included gender as the only covariate for which we had data for all study subjects (n = 920). The effect of the training program was not modified by gender or age group. However, irrespective of study group, the relative risk of injury was greater for girls in comparison to boys [RR = 1.64 (95% CI; 1.14–2.33)]. This was consistent for acute injury [RR = 1.47 (95% CI; 1.02–2.13)] and lower-extremity injury [RR = 1.64 (95% CI; 1.1–2.38)].

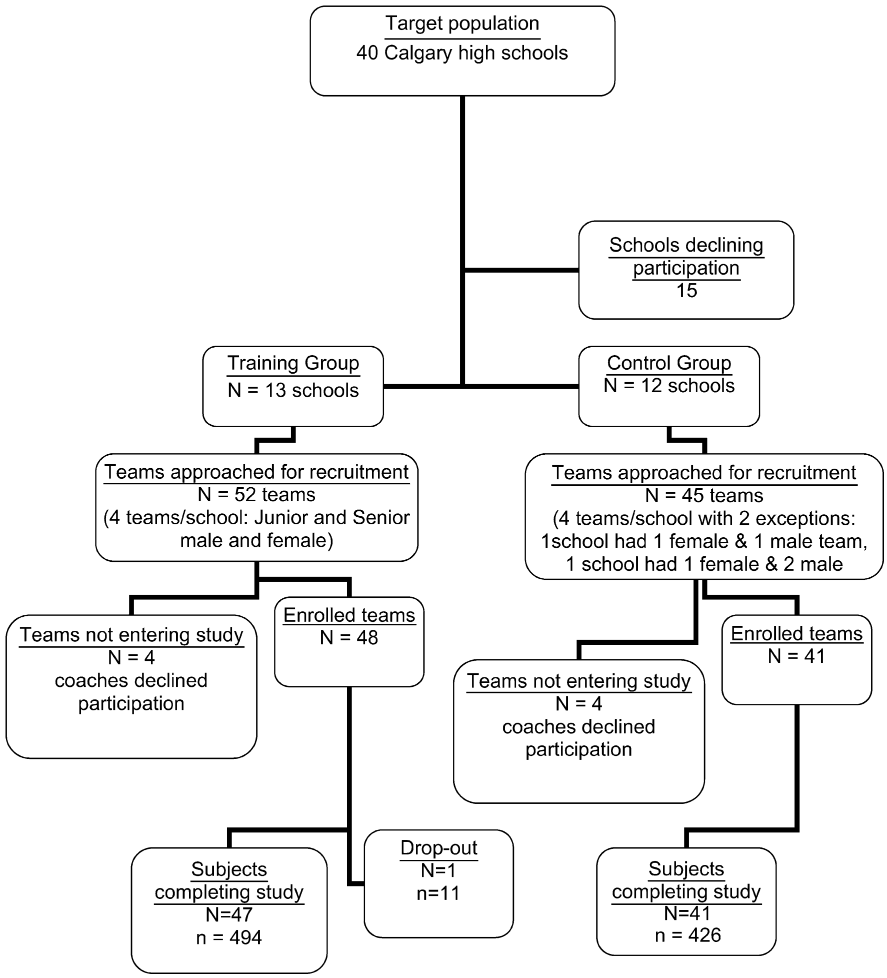

FIGURE 1. Flow chart outlining selection of schools, teams, and participants.

Data regarding baseline covariates were missing for some study subjects. Previous injury data from the baseline medical questionnaire were complete for 740 of 920 study subjects (80.4%). The proportion of subjects completing specific preseason baseline measurements were as follows: height (97.1%), weight (97.8%), vertical jump (92.8%), dynamic balance (93.4%), and 20 meter shuttle run (68.2%). A multivariate Poisson regression analysis, including all significant

TABLE 1. Baseline Characteristics for Both Training and Control Groups

Baseline Characteristic	Training Group* (n = 494)	Control Group* (n = 426)
Age (years)	Median 16 (range 13–18)	Median 16 (range 12–18)
Gender	Female = 250/494 = 50.6% Male = 244/494 = 49.4%	Female = 206/426 = 48.4% Male = 220/426 = 51.6%
Injury in the previous year (ankle sprain)	15.3% (95% CI; 11.0–19.5)	14.8% (95% CI; 10.7–18.8)
Injury in the previous year (all injury)	37.3% (95% CI; 31.6–43.0)	38.4% (95% CI; 33.1–43.7)
Height (m)	1.75 (95% CI; 1.73–1.77)	1.75 (95% CI; 1.72–1.77)
Weight (kg)	65.9 (95% CI; 64.0–67.7)	66.4 (95% CI; 64.0–68.8)
Body mass index (kg/m^2)	21.5 (95% CI; 21.1–21.8)	21.7 (95% CI; 21.2–22.1)
Vertical jump (cm)	Female 38.4 (95% CI; 36.6–40.2) Male 53.4 (95% CI; 51.4–55.3)	Female 36.8 (95% CI; 34.7–38.9) Male 53.2 (95% CI; 51.0–55.5)
Predicted VO_2max (mL/kg/min) (20 m shuttle run)	Female 37.7 (95% CI; 35.1–40.4) Male 47.0 (95% CI; 45.1–48.9)	Female 37.3 (95% CI; 35.8–38.8) Male 45.2 (95% CI; 42.9–47.5)
Left handed	8.9% (95% CI; 3.6–8.8)	6.2% (95% CI; 5.2–12.7)
Dynamic balance maximum (seconds)	5.2 (95% CI; 4.9–5.7)	5.2 (95% CI; 4.8–5.5)

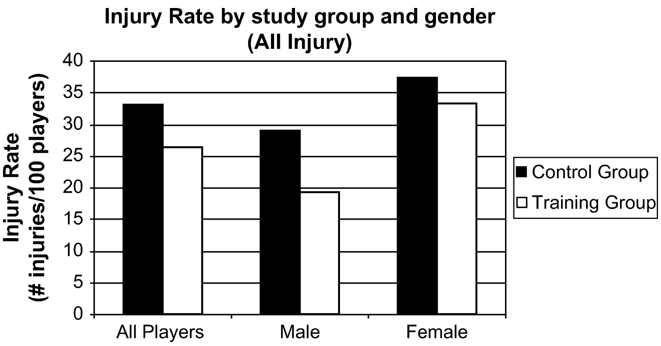

FIGURE 2. Injury Rate (All Injury) by study group and gender.

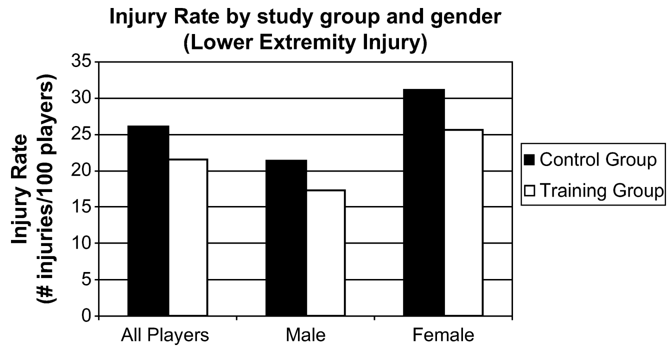

FIGURE 4. Injury Rate (Lower-Extremity Injury) by study group and gender.

baseline covariates (n = 740), revealed that the effect of the training program was not modified by gender, previous lower-extremity injury, age, or other baseline covariates. Additionally, there was an increased risk of all injury [RR = 1.64 (95% CI; 1.27–2.12)], lower-extremity injury [RR = 1.57 (95% CI; 1.17–2.1)], and ankle sprain injury [RR = 1.52 (95% CI; 1.07–2.14)] in players reporting a previous lower-extremity injury in the past year.

Acute injuries accounted for 95% (95% CI; 90.0–98.0) of all injuries in the control group and 83.8% (95% CI; 76.4–89.7) in the training group. The remaining injuries were classified as gradual-onset injuries. The most frequently occurring specific injury type was ankle sprain, accounting for 53.9% (95% CI; 45.3–62.3) of all injuries in the control group and 47.7% (95% CI; 38.9–56.6) of all injuries in the training group. The second most common specific injury type was acute knee injuries (including all ligament sprains and meniscus tears), which accounted for 9.2% (95% CI; 5.0–15.3) of all injuries in the control group and 13.8% (95% CI; 8.4–21.0) in the training group.

Injury severity was classified as minor (0–7 days time loss from basketball), moderate (8–21 days time loss), or severe (>21 days time loss from basketball). The proportions of injuries in the control group by injury severity classification were as follows: minor 74.3% (95% CI; 66.1–81.4), moderate 16.2% (95% CI; 10.4–23.5), and severe 9.6% (95% CI; 5.2–15.8). The proportions of injuries in the training group by injury severity classification were as follows: minor 71.3% (95% CI; 62.7–78.9), moderate 10.1% (95% CI; 5.5–16.6), and severe 18.6% (95% CI; 12.3–26.4). The proportion of injuries classified as minor, moderate, and severe did not differ by training group.

Self-report compliance data were returned by 362/494, or 73.3%, of training group participants. Self-reported compliance indicated that only 298/494, or 60.3%, of the training school players participated in the home-based wobble board training program at all beyond the designated team warm-up activities. The assumption is that those not completing compliance journals did not participate in the home program. The median self-reported number of sessions was 9 (range: 0–43) during the initial 6 week period of training.

DISCUSSION

The objective of this study was to examine the effectiveness of a balance training program in reducing injury rates in high school basketball. This training program was effective in reducing the risk of acute-onset injuries in high school basketball players [RR = 0.71 (95% CI; 0.5–0.99)]. There is arguably a clinical trend related to the protective effect of the wobble board training program in reducing all injury, lower-extremity injury, and ankle sprain injury despite lack of statistical significance in an intent-to-treat analysis controlling for cluster randomization design. The intracluster correlation coefficient based on injury rate observed in this study was $P = 0.06$. Also, the effect size observed was 20%, not 33% on

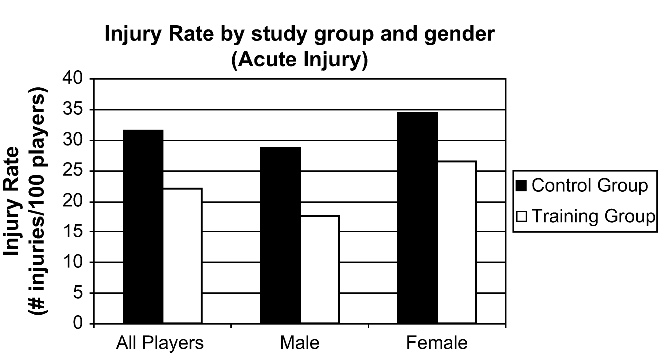

FIGURE 3. Injury Rate (Acute Injury) by study group and gender.

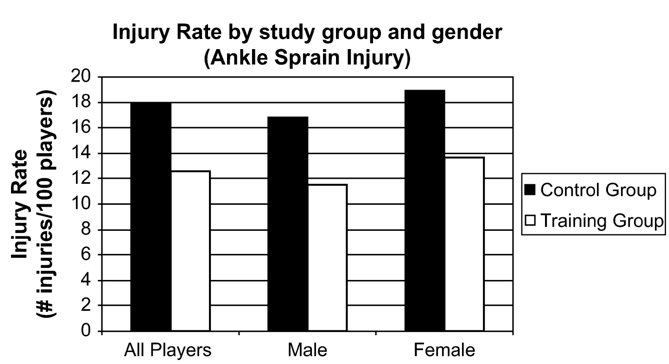

FIGURE 5. Injury Rate (Ankle Sprain Injury) by study group and gender.

TABLE 2. A Comparison of Injury Rates, Including Exposure (ie, Injuries per 1000 Player Hours), by Injury Type, Based on Intent-to-Treat Poisson Regression Analysis (n = 920)

Training Group, Gender, and Injury Type	Total Player Exposure Hours	Number of Injuries	Injury Rate (injuries per 1000 player hours)	Relative Risk	95% Confidence Interval (cluster-adjusted)	Statistical Significance (Z test)
All injury						
Control (All)	34,955	141	4.03 (95% CI; 3.4–4.76)	1		
Training (All)	39,369	130	3.3 (95% CI; 2.76–3.92)	0.8	(0.57–1.11)	*P* = 0.18
All acute injury						
Control (All)	34,955	134	3.83 (95% CI; 3.21–4.54)	1		
Training (All)	39,369	109	2.77 (95% CI; 2.27–3.34)	0.71	(0.5–0.99)	*P* = 0.047*
Lower-extremity injury						
Control (All)	34,955	111	3.18 (95% CI; 2.61–3.82)	1		
Training (All)	39,369	106	2.69 (95% CI; 2.2–3.26)	0.83	(0.57–1.19)	*P* = 0.3
Ankle injury						
Control (All)	34,955	76	2.46 (95% CI; 1.97–3.04)	1		
Training (All)	39,369	62	1.57 (95% CI; 1.21–2.02)	0.71	(0.45–1.13)	*P* = 0.15

*Statistically significant finding ($P < 0.05$).

which our sample size calculation was based. As such, post hoc power analysis suggests that we would have needed 980 participants (11 players from each of 90 teams) in each study group to detect a 20% reduction in injury rate ($1-\beta = 0.8$, $\sigma = 0.05$).

The observed injury rate in the control group in our study was 33.1 injuries per 100 participants per season (95% CI; 28.64–37.79) for all injuries. This is consistent with other studies examining injury rates in adolescent basketball.[26] Females were at a higher risk of injury than males for all injuries, consistent with Messina et al's findings in high school basketball in Texas.[27] Lower-extremity injuries accounted for 78.7% and ankle sprains accounted for 53.9% of all injuries in our control group, also consistent with other findings.[26] Players that had a previous injury in the last 1 year sustained more injuries than those that did not report a previous injury. These results are supported by many studies that suggest previous injury is a major risk factor for injury in adolescent sport.[4]

Balance training in conjunction with other preseason training strategy components has been shown to reduce the incidence of injury in sports such as European handball, soccer, basketball, and volleyball between 38% and 87%.[28–38] These studies have demonstrated a protective effect consistent with the point estimates for relative risk found in our study; however, cluster randomization has been largely ignored in the analysis with the exception of Olsen et al, who demonstrate an overall protective effect of a multifaceted neuromuscular training program in reducing all injury in adolescent European handball players and use an appropriate cluster-adjusted analysis [RR = 0.49 (95% CI; 0.39–0.63)].[36] They also found a significant protective effect specifically of acute-onset injuries [RR = 0.51 (95% CI; 0.39–0.66)].[36] The greater protective effect found in club-level European handball is likely related to the greater reported compliance (87%) and a more extensive team-based multifaceted neuromuscular training intervention of which wobble board training was 1 component. McGuine et al[37] demonstrate a protective effect of a team-based balance training program, which was commenced 4 weeks prior to the season, in reducing ankle sprain injuries in high school basketball and soccer players [RR = 0.56 (95% CI; 0.33–0.95)]. Emery et al[38] also demonstrated a significant protective effect of this home-based wobble board training program, while controlling for cluster randomized design, in healthy adolescents where individual training was provided biweekly by a physiotherapist and reported compliance was greater (median 3 times per week; range 1–7). One of the limitations in this study, compared to McGuine et al[39] was that access to players for recruitment in our study was not permitted until 1 week prior to the start of basketball season, when teams were formed. As such, players were commencing the training program just prior to the first game of the basketball season, not during a preseason period.

Although the estimation of some WES data was a limitation in this study, the proportion of WES data estimated did not differ between study groups and thus was unlikely to introduce bias. In addition, "partial" participation reflecting <75% participation was recorded in all cases to be 50% of full session hours. Although this procedure may have slightly overestimated or underestimated total exposure hours, it did not differ by study group so is also unlikely to introduce bias.

This balance training program was effective in reducing acute-onset injuries by 29%. However, further studies will be required to confirm the effectiveness of a more extensive multifaceted neuromuscular training program, including a wobble board training component, in adolescent basketball. High rates of lower-extremity injury are not limited to high school basketball players; it also occurs in sports such as soccer.[3,4,28] As such, future studies should target alternate adolescent sport populations. Further examination of methods to improve compliance to such an adolescent injury prevention program is necessary. In addition, the cost effectiveness of this program should be evaluated. Future research should include long-term follow-up of sport injury in adolescents, examining physical activity, osteoarthritis, and chronic pain outcomes.

CONCLUSIONS

This is the first single-blind cluster RCT examining an injury-prevention strategy in adolescent sport. We have established the feasibility of doing a prevention cluster RCT in community adolescent sport using a valid injury surveillance system. We found a significant protective effect of a basketball-specific balance training program in reducing acute-onset injuries in high school basketball. Arguably, a clinically relevant trend was also found with respect to all injury, lower-extremity injury, and ankle sprain injury. These findings will be instrumental in developing and refining further prevention strategies in adolescent basketball and other adolescent sport.

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