Prevention of Ankle Sprain Injuries in Youth Soccer and Basketball: Effectiveness of a Neuromuscular Training Program and Examining Risk Factors

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Abstract

Objectives: The primary objective of this study was to examine the effectiveness of a neuromuscular training (NMT) warm-up program in reducing the risk of ankle sprain injury (ASI) in youth soccer and basketball. The secondary objective included the evaluation of risk factors for ASI. **Study Design:** Secondary analysis of pooled data from 5 studies. **Participants:** Male and female youth (11-18 years) soccer and basketball players (n = 2265) in Alberta, Canada. **Outcome Measures:** Ankle sprain injury was the primary outcome and was recorded using a validated prospective injury surveillance system consistent in all studies. The primary exposure of interest was NMT warm-up, which included aerobic, strength, agility, and balance components. Multivariable Poisson regression, controlling for clustering by team and offset for exposure hours, was used to estimate incidence rate ratios (IRRs) with 95% confidence intervals (CIs), with considerations for confounding and effect modification and evaluating all covariates as potential risk factors. **Results:** A total of 188 ASIs were reported in 171 players. Neuromuscular training significantly reduced the risk of ASI [IRR = 0.68 (95% CI; 0.46-0.99)]. Independent risk factors for ASI included previous ASI [IRR = 1.98 (95% CI; 1.38-2.81)] and participation in basketball versus soccer [IRR = 1.83 (95% CI; 1.18-2.85)]. Sex, age, body mass index, and previous lower extremity injury (without previous ASI) did not predict ASI ($P > 0.05$). **Conclusions:** Exposure to an NMT program is significantly protective for ASI in youth soccer and basketball. Risk of ASI in youth basketball is greater than soccer, and players with a history of ASI are at greater risk.

Key Words: injury prevention, ankle injury, randomized controlled trial, adolescents

(*Clin J Sport Med* 2017;0:1–7)

INTRODUCTION

Ankle sprain injury (ASI) is the most common injury in youth soccer and basketball.[1–6] A large-scale systematic review comprising several studies from 38 different countries around the world revealed that the ankle ranked the most frequently injured body part in sports with a weighted prevalence of 34%, mostly ASIs.[6] Specifically, ASI constitutes 77% and 91% of all ankle injuries in soccer and basketball, respectively.[6] Evidence indicates that there is a 2-fold increased risk of a second ASI for at least 1 year after injury for an index ASI, which suggests ongoing dysfunction and/or a greater predisposition for an ASI risk.[7,8] The long-term consequences of ASI may include, but not limited to chronic ankle instability, overweight/obesity and posttraumatic osteoarthritis.[8–11]

There is consistent evidence that neuromuscular training (NMT) warm-up programs can reduce the risk of acute lower extremity injuries (LEIs) ranging from 29% to 60% in youth sports.[12–19] Although some randomized controlled trials (RCTs) have reported a significant protective effect of NMT on ASI and ankle injuries,[7,20–26] others have reported no significant risk reduction.[13,15,19,27,28] As most studies were not specifically aimed at and powered for evaluating the effects of NMT on ASI risk, combining data from studies with comparable injury surveillance methodologies offers opportunities for increased statistical power to specifically test the effectiveness of NMT warm-up strategies in reducing the risk of ASI.

Risk factors for injury in professional soccer and basketball are generally well investigated.[5,29–37] However, little is known about the risk factors specifically for ASI in these sports.[38–40] Identifying risk factors specific for ASI in youth soccer and basketball will inform explicit recommendations for ankle sprain prevention strategies for players.

The primary objective of this study was to assess the effectiveness of an NMT warm-up program in reducing the risk of ASI in youth soccer and basketball in a large sample of players, and the secondary objective was to examine sex, age, sport, body mass index (BMI), previous history of ASI, and LEI as independent risk factors for ASI.

METHODS

A secondary data analysis including data from 3 cohort studies[35,41,42] and 2 RCTs[19,28] previously conducted in one season of play in youth (11-18 years) male and female soccer and basketball in Alberta, Canada (2005-2011), was completed. Common injury surveillance procedures—including

Submitted for publication July 18, 2016; accepted February 21, 2017.

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The authors report no conflicts of interest.

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http://dx.doi.org/10.1097/JSM.0000000000000462

baseline medical questionnaire, baseline assessment, daily participation exposure data, and injury report forms—were used in all 5 studies. Summary of study designs and main results are presented in Table 1.

Study Outcome, Procedure, and Intervention

The outcome of this secondary analysis was ASI per 1000 player hours. The injury definition included any ASI occurring during sport participation that required medical attention and/or resulted in a player not completing a session and/or missing a subsequent session. Diagnosis of ASI was made by a physiotherapist or certified athletic therapist. Daily player participation was recorded in all 5 studies. Each participating team was assigned a team designate (ie, team trainer, coach, or manager) who recorded all daily participation exposure data on a weekly exposure sheet for every game and practice. The team designate also initiated an injury report form for any reportable injury. A "full" session was assigned if the player had completed 75% to 100% of a session, a "partial" session if a player had participated less than 75%, and "no participation" if the player missed the entire session because of injury, sickness, or other reasons. In the event of a soccer or basketball injury, the player was given an injury identification number that was included on an injury report form on which the physiotherapist or certified athletic therapist documented all injuries.

The primary exposure of interest was participation in a 15-minute NMT warm-up intervention program before every practice session. The NMT components comprised aerobic, static and dynamic stretching, strength, agility, and balance components. As part of the intervention in the NMT group, participants were also instructed to observe a 15- to 20-minute home-based balance training program (using a 16-inch diameter wobble board). Full details of each study design and procedures included in this secondary analysis have been previously reported.[19,28,35,41,42]

Data Management and Statistical Analyses

Independent variables include NMT (primary exposure), sex, age, weight, height, BMI, sport, previous ASI, and previous LEI (with or without previous ASI in the past 1 year) (covariates). All covariates were consistently reported in the 5 studies. Univariate and multivariable analyses were used to examine the relationship between NMT and ASI risk and also examine the relationship between potential risk factors and ASI risk. In the multivariable analyses, BMI was included as a covariate, and weight and height were excluded to prevent collinearity. Also, to exclude collinearity between previous ASI and all previous LEI while still examining previous LEI as a potential risk factor for ASI, a new variable—previous LEI (without previous ASI)—was generated, and this was used in the multivariable Poisson regression analysis. Participants with missing values were excluded from analyses.

Statistical analyses were performed using STATA (version 14.1, College Station, Texas). Player characteristics were reported using descriptive statistics [frequencies, proportions, means (95% confidence intervals) (CIs)]. Injury incidence rates were expressed as number of injuries/1000 hours. Univariate Poisson regression analyses, controlling for clustering by team and offset for player exposure hours, were used to estimate unadjusted incidence rate ratios (IRRs) with 95% CIs to examine the association between independent variables and risk of ASI. Variables including age, weight, height, and BMI were categorized from a continuous scale. Age was dichotomized into

TABLE 1. Summary of Studies Included in Secondary Data Analysis

Study Title	Design	Main Results
1. Evaluation of risk factors for injury in adolescent soccer[35]	Cohort study	The overall injury rate during the regular season was 5.59 injuries/1000 h (95% CI; 4.42-6.97). Ankle and knee injuries were the most common injuries reported. There were significant differences in injury rates found by division, previous injury, and session type (practice vs game).
2. Risk factors for injury in indoor compared with outdoor adolescent soccer[41]	Cohort study	The overall injury rate found in indoor soccer was 4.45 injuries/1000 h (95% CI; 3.1-6.19). The overall injury rate found in outdoor soccer among a similar cohort was 5.59 injuries/1000 h (95% CI; 4.42-6.97). There was no significant difference between injury rates by age group or sex in indoor soccer compared with outdoor soccer.
3. Preseason musculoskeletal screening: identifying risk factors for injury in female youth soccer players[42]	Cohort study	The overall injury rate was 3.28 injuries/1000 h (95% CI; 2.32-4.5), of which 84.2% were LEIs. Lower extremity injury risk was associated with high-risk single leg squat (IRR = 2.06, 95% CI; 1.01-4.22), older age (ages 14-17 compared with ages 11-13; IRR = 1.55, 95% CI; 1.05-2.28), and lower level of elite play (tier 2 compared with tier 1; IRR = 2.0, 95% CI; 1.12-3.57).
4. A prevention strategy to reduce the incidence of injury in high school basketball: a cluster-randomized controlled trial[28]	Cluster-randomized controlled trial	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)], LEI [RR = 0.83 (95% CI; 0.57-1.19)], and ASI [RR = 0.71 (95% CI; 0.45-1.13)] was not statistically significant.
5. The effectiveness of a neuromuscular prevention strategy to reduce injuries in youth soccer: a cluster-randomized controlled trial[19]	Cluster-randomized controlled trial	The injury rate in the training group was 2.08 injuries/1000 hours and in the control group 3.35 injuries/1000 h. The IRRs for all injuries and acute-onset injury were 0.62 (95% CI; 0.39-0.99) and 0.57 (95% CI; 0.35-0.91). An NMT program is protective of all injuries and acute-onset injury in youth soccer players.

2 categories, 11- to 15-year-olds and 16- to 18-year-olds, based on the median of 15 years. For the purpose of univariate analysis, weight was stratified into upper 25th percentile and lower 75th percentile based on age categories. Similarly, height was stratified based on age categories and sports considering the high variability between soccer and basketball players. Body mass index was classified using the standard age- and sex-specific BMI percentiles for children and adolescents.[43]

In the Poisson regression model, covariates were assessed for confounding and effect modification (sex, age, and previous ASI) in examining the association between NMT and ASI risk while controlling for clustering by team and offset for player exposure hours. Furthermore, covariates were examined as independent risk factors for ASI. A stepwise backward elimination was done (manually), in which effect modifiers and/or covariates showing significance at the 5% level were kept in the final model. Also, covariates that changed the estimate of the beta coefficient of the primary exposure (NMT) by more than 10% were considered as confounders.

RESULTS

Player Characteristics

There were 188 ankle sprains in 171 players recorded from an overall population of 2265 players [mean age (SD) = 14.95 (1.45) years; range = 11-18 years] in a total of 150 818 hours of exposure. Player characteristics are shown in Table 2.

TABLE 2. Player Characteristics

	NMT (n = 874)	No NMT (n = 1391)
Variables	**Mean (95% CI)**	**Mean (95% CI)**
Age, yr	15.11 (15.03-15.20)	14.85 (14.77-14.93)
Weight, kg	61.54 (60.69-62.34)	59.59 (58.91-60.27)
Height, m	1.71 (1.71-1.72)	1.68 (1.67-1.69)
BMI, kg/m^2	20.83 (20.62-21.04)	20.92 (20.76-21.08)
Exposure time, h	72.56 (70.98-74.15)	62.92 (61.48-64.37)
	Frequency (%)	**Frequency (%)**
Sex		
Females	469 (53.7)	952 (68.4)
Males	405 (46.3)	439 (31.6)
Sport		
Soccer	380 (43.5)	965 (69.4)
Basketball	494 (56.5)	426 (30.6)
Previous ASI		
No	671 (76.8)	1150 (82.7)
Yes	58 (6.6)	91 (6.5)
Missing	145 (16.6)	150 (10.8)
Previous LEI (all)		
No	587 (67.2)	904 (65.0)
Yes	142 (16.2)	334 (24.0)
Missing	146 (16.6)	150 (11.0)
Previous LEI (without ASI)		
No	645 (73.8)	998 (71.8)
Yes	84 (9.6)	243 (17.5)
Missing	145 (16.6)	150 (10.8)

Univariate Analysis

Univariate analyses demonstrated a protective effect of NMT on ASI but without a statistical significant association [IRR = 0.71 (95% CI; 0.50-1.01)]. However, the older age group [IRR = 1.50 (95% CI; 1.02-2.02)], basketball versus soccer [IRR = 1.68 (95% CI; 1.15-2.47)], previous ASI [IRR = 2.38 (95% CI; 1.66-3.42)], and previous LEI (All) [IRR = 1.91 (95% CI; 1.45-2.51)] were significantly associated with the increased risk for ASI (Table 3).

Multivariable Analysis

A multivariable Poisson regression model (adjusted for covariates and clustering by team, using total hours of sport participation as an offset) demonstrated that NMT significantly reduced the risk of ASI [IRR = 0.68 (95% CI; 0.46-0.99)]. Previous ASI [IRR = 1.98 (95% CI; 1.38-2.81)] and basketball versus soccer [IRR = 1.83 (95% CI; 1.18-2.85)] were independently associated with increased risk of ASI in the final model (n = 1947) (Table 4). There was no evidence of confounding by any of the covariates or effect-measure modification by sex, age category, or previous ASI in the relationship between NMT and ASI risk ($P > 0.05$).

DISCUSSION

This study shows that an NMT warm-up program had a protective effect in reducing the risk of ASI by 32%. Further, previous ASI and participation in basketball versus soccer were found to be independent risk factors for ASI in a large sample of youth soccer and basketball players. We observed some imbalances in the baseline measures for the current study. This is not surprising considering the study design and the fact that we had to pool data across 5 studies. To address this potential bias, a robust multivariate regression analysis was run accounting for covariates and team clusters; total hours of sport participation as an offset.

Effectiveness of Neuromuscular Training Program on Ankle Sprain Injury Risk

This study demonstrates the effectiveness of NMT warm-up program in reducing the risk of ASI in youth soccer and basketball players. Neuromuscular training warm-up programs have previously been consistent in demonstrating the protective effect in reducing the risk of LEIs in multiple sport populations involving youths and adults. However, current evidence demonstrates mixed results on the effectiveness of NMT programs, specifically in the prevention of ASI in these populations.[7,13,15,19–28] Five of these studies specifically relate to youth sport and recreation.[13,15,19,26,28] Of these 5 studies, only one study reported a statistically significant reduction in ASI after an exposure to a high-intensity NMT warm-up program during physical education in schools.[26] The most plausible reason for lack of statically significant effect of NMT on ASI risk in both youth and adult sports is that previous studies have not been primarily powered to examine the effectiveness of NMT on reducing the risk of ASI specifically.

Although the actual size of the protective effect of NMT on ASI risk is of utmost clinical relevance, having a robust understanding on the direction of the effect using regression analyses adjusting for important covariates that may potentially confound or modify the effect of NMT on ASI provides

TABLE 3. Injury Incidence Rates and IRRs for Risk of ASIs in Players

Exposure Variables	Exposure, h	No of Ankle Sprains	Crude IR/1000 h (96% CI)	IRR* (Cluster-Adjusted) (95% CI)	*P*
NMT					
No	87 398	124	1.42 (1.18-1.67)	1	
Yes	63 420	64	1.01 (0.78-1.23)	0.71 (0.50-1.01)	0.058
Sex					
Female	92 827	109	1.17 (0.96-1.42)	1	
Male	57 992	79	1.36 (1.08-1.70)	1.16 (0.75-1.80)	0.497
Age category, yr					
11-15	91 273	95	1.04 (0.84-1.27)	1	
16-18	59 545	93	1.56 (1.26-1.91)	1.50 (1.02-2.02)	0.038†
Weight, kg‡					
Lower 75th percentile	104 651	123	1.18 (0.98-1.40)	1	
Top 25th percentile	46 168	65	1.41 (1.09-1.79)	1.20 (0.82-1.75)	0.361
Height, m§					
Lower 75th percentile	48 352	103	2.13 (1.74-2.58)	1	
Top 25th percentile	17 653	65	3.68 (2.84-4.69)	1.11 (0.74-1.64)	0.618
BMI, kg/m^2					
Normal	123 526	151	1.22 (1.04-1.43)	1	
Overweight/obese	17 273	23	1.33 (0.84-2.00)	1.08 (0.71-1.66)	0.710
Sport					
Soccer	76 494	71	0.92 (0.72-1.17)	1	
Basketball	74 324	117	1.57 (1.30-1.89)	1.68 (1.15-2.47)	0.008†
Previous ASI					
No	120 277	141	1.17 (0.99-3.02)		
Yes	11 403	32	2.80 (1.92-3.95)	2.38 (1.66-3.42)	<0.001†
Previous LEI (all)					
No	99 539	107	1.08 (0.88-1.23)	1	
Yes	32 168	66	2.05 (1.59-2.61)	1.91 (1.45-2.51)	<0.001†
Previous LEI (without ASI)					
No	110 474	139	1.26 (1.06-1.47)	1	
Yes	20 639	34	1.65 (1.14-2.30)	1.32 (0.93-1.88)	0.120

** Univariate analyses—Poisson regression adjusted for clustering by team and offset for exposure hours.*
† Significant at $P < 0.05$.
‡ Stratification by age.
§ Stratification by age and sport.

us a clear understanding of this relationship. The current study evaluated the relationship between NMT and ASI risk considering the aforementioned. A sizeable effect of 32% ASI reduction reported in the regression model generated in our study is consistent with current evidence in studies of youth sports, in which the protective effect of NMT on ASI injury risk has been reported to range from 29% to 73%.[13,15,19,26,28]

The nonsignificant protective effect of NMT program on ASI risk in univariate analysis and evidence of significant protective effect in the multivariate analysis model including previous ASI as a covariate suggest the possibility of an effect-measure modification by previous ASI irrespective of lack of statistical significance in the multiplicative interaction term ($P = 0.155$). It is important to mention that this study might not have had adequate power to detect any significant interaction effects within the subgroups of players with or without previous ASI based on the conventional type 1 error rate of 5% ($\alpha = 0.05$).[44,45] Thus, the lack of statistical evidence in effect-measure modification by previous ASI is not an indication that no clinically relevant difference exists in the protective effect of NMT across the strata of previous ASI.[44,46] The significant protective effect of NMT on ASI risk demonstrated in our study is consistent with findings of previous research and is perhaps dependent on the history of previous ASI in young athletes.[25,47,48] It seems that the protective effect of the NMT is mostly manifested in players with a previous history of ASI as consistently demonstrated by previous research.[25,47–49] We recommend that future studies should attempt using both multiplicative and additive effect-measure modification to draw conclusions about the effect size and statistical significance of previous ASI as a modifier in the efficacy of NMT programs on ASI risk in youth sport.

The NMT program implemented in the studies included in our secondary analysis is multifaceted and as such not specific

TABLE 4. Adjusted IRR for ASI in Youth Soccer and Basketball Players (n = 1947)*

Risk Factors	IRR (95% CI)	*P*
NMT		
No	1	
Yes	0.68 (0.46-0.99)	0.045†
Previous ASI		
No	1	
Yes	1.98 (1.38-2.81)	<0.001†
Sport		
Soccer	1	
Basketball	1.83 (1.18-2.85)	0.007†

Final model adjusted for clustering by team and offset for exposure hours. Initial model included NMT, sex, age category, BMI, previous ASI, previous LEI (without ASI), sport and interactions between NMT and sex, age category, and previous ASI.
** Participants with missing values were excluded from the model.*
† Significant at $P < 0.05$.

for the ankle joint. Future research should consider the possibility that NMT warm-up components could be more specific to ankle injury; this could maximize the protective effect of NMT interventions. Further, program compliance/adherence will contribute to the effectiveness of NMT as recent studies suggest a dose–response effect of NMT on injury risk.[12,16,26,50] Thus, team compliance (for controlled trials) and adherence (for noncontrolled trial) to NMT programs should be a major concern in sport injury prevention, as this can significantly impact study outcomes.[51] Future research should also consider evaluating strategies for optimal uptake and maintenance of NMT programs for the utmost preventive effect on ASIs.

Risk Factors for Ankle Sprain Injury

The risk factors for injuries in adolescent and youth sport have been well explored in the literature. Risk factors include age, sex, poor physical performance (endurance/dynamic balance), poor coaching, previous injury, and some psychosocial factors.[5,35,41,52–54] Propositions have been made for sport- and diagnosis-specific evaluation of risk factors for exclusive prevention of injuries.[54,55] The current study suggests that risk factors for ASI in youth soccer and basketball are similar to those reported for general LEIs in youth sport and in soccer and basketball.[5,30,35,41] Univariate analyses demonstrate that older age (16-18 vs 11-15 years), basketball versus soccer participation, previous ASI, and previous LEI (All) were significant predictors of ASI. However, only previous ASI and basketball versus soccer participation were significant predictors of ASI in multivariable Poisson regression analyses. Given that previous literature demonstrates all previous LEIs are risk factors for new LEIs in youth sport,[35,52,56] it was important to specifically examine previous LEI with and without previous ASI as a risk factor for ASI. Both univariate and multivariable analyses in the current study reveal that previous LEI is only a predictor of ASI if inclusive of previous ASI; a previous history of all other types of LEI does not predict ASI in youth soccer and basketball players.

Contrary to previous studies in which BMI was found to predict ASI risk in youth (American) football,[57,58] our study showed that BMI was not related to ASI risk in both univariate and multivariable regression analyses. This finding suggests that the relationship between BMI and ASI risk may be sport specific, and BMI is not a predictor of ASI risk in youth soccer and basketball players.

Study Limitations

There are limitations related to the protective and risk factor evaluation in this study. Our risk factor evaluation was limited to those reported across the 5 studies that constituted this secondary analysis. For example, there is evidence that the use of ankle brace can reduce the incidence of acute ASI in youth sport.[59–61] We would have been interested in examining the use of ankle brace as a covariate in the multivariable regression analyses. Use of ankle brace by players during soccer and basketball participation was not documented in 2 of the 5 studies.

Similarly, measures such as the star excursion balance, single-leg dynamic balance, predicted $\dot{V}O_2$max tests, and playing surface for soccer (eg, turf vs grass) were not documented across all studies. Thus, adjustment for confounders in the multivariable analyses was only possible for covariates that were reported for the 5 studies. As such, there is possibility for residual confounding that might have impacted the estimates derived for NMT and risk factors evaluated. Nevertheless, major factors such as sex, age, BMI, previous ASI, and previous LEI established as risk factors in youth sport in other studies were available for all analyses. Furthermore, estimation of compliance/adherence rate to the NMT program and analysis on the dose–response effect of NMT on the risk of ASI was not possible for this study, as there was inadequate data in pooled study data for such analysis. Lastly, the generalizability of these findings beyond youth soccer and basketball should be considered with caution.

CONCLUSION

Exposure to an NMT warm-up program significantly protects against ASI in youth soccer and basketball players. Although there was no statistical evidence of effect-measure modification, the observed protective effect seems to manifest differently in players with and without history of previous ASI. Risk of ASI in youth basketball is greater than soccer and players with a history of ASI are at greater risk. Sex, age, BMI, and previous LEI (excluding previous ASI) do not predict ASI in youth soccer and basketball. This study will inform future research evaluating the implementation of NMT strategies in youth soccer and basketball for the greatest public health impact.

ACKNOWLEDGMENTS

The Sport Injury Prevention Research Centre is one of the International Research Centres for Prevention of Injury and Protection of Athlete Health supported by the International Olympic Committee. We acknowledge the funding from Alberta Innovates Health Solutions. Dr Carolyn Emery holds a Chair in Pediatric Rehabilitation through the Alberta Children's Hospital Foundation. The authors acknowledge Calgary Minor Soccer Association and Calgary Board of Education and all the coaches, teachers, and

players involved for their time and support informing this research project.

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