Implementing a School-based Prevention Program to Reduce Injuries through Neuromuscular Training (iSPRINT): A cluster-randomized controlled trial

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**ABSTRACT**

**Objectives:** To evaluate the effectiveness of iSPRINT, implementing a School Prevention Program to Reduce Injuries through Neuromuscular Training (NMT), when delivered in junior high school physical education.

**Methods:** This was a cluster-randomized controlled trial. Students were recruited from 12 Calgary junior high schools (2014-2017). iSPRINT is a 15-min NMT warm-up including aerobic, agility, strength, and balance exercises. Following a workshop, teachers were asked to deliver the 12-week iSPRINT NMT (6 schools) or a standard-of-practice warm-up (6 schools) in PE classes. The all recorded injury definition included those that resulted in the inability to complete a S&R session, time loss and/or medical attention. Incidence rate ratios (IRR) were estimated based on multiple multilevel Poisson regression analyses [adjusting for sex (considering effect modification), previous injury, offset by S&R participation hours and school and class level random effects were examined] for intent to treat analyses.

**Results:** 1067 students (ages 11-16) were recruited across 12 schools [6 intervention schools (22 classes), 6 control schools (27 classes); 53.7% female, 46.3% male). The iSPRINT program was protective of all recorded S&R injury for girls (IRR=0.543; 95% CI: 0.295,0.998)], but not boys (IRR=0.866; 95% CI: 0.425,1.766). The iSPRINT program was also protective of each of lower extremity (LE) injuries (IRR=0.357; 95%CI: 0.159,0.799) and medical attention injuries (IRR=0.289; 95% CI: 0.135,0.619) for girls, but not boys (IRR=1.055; 95% CI: 0.404,2.753) and (IRR=0.639; 95% CI: 0.266,1.532), respectively].

**Conclusion:** The iSPRINT NMT warm-up was effective in preventing each of all recorded injury, lower extremity injury and medically treated S&R injuries in female junior high school students.

| **What are the new findings?** |
| --- |
| • A teacher-delivered NMT warm-up program was effective in preventing each of all recorded injuries, lower extremity injuries and medically treated injuries in girls in junior high school (ages 11-16).<br>• A teacher-delivered NMT warm-up program was not found to be effective in preventing all recorded injury in boys in junior high school (ages 11-16). |

| **How might it impact on clinical practice in the future?** |
| --- |
| • A teacher-delivered NMT warm-up program is recommended as minimal standard-of-practice for injury prevention in youth S&R junior high school physical education (ages 11-16).<br>• Further research is needed to evaluate the effect of exercise fidelity and differences in exercise fidelity between girls and boys when completing a teacher-delivered NMT warm-up program. |

## Introduction

Childhood physical activity promotes healthy growth and development and prevents chronic disease.[1] In Canada, the proportion of obese children has tripled over the past 25 years.[2] While we strive for an active population, participation in any physical activity must be balanced with the risk of injury. Sport and recreation (S&R) is the leading cause of injury in youth in Canada.[3,4] Rates of sport participation are high, with significant rates of participation in organized sport.[5,6] Injuries represent over 30% of Emergency Department visits in those ages 7-24.[7] It is expected that every year in Canada, 30-40% of youth (ages 11-19) will sustain a S&R injury requiring medical attention.[5,6] Ice hockey, skiing and snowboarding, basketball and soccer are among the activities that lead to the most injuries in Alberta youth.[3,4,8] Overweight/obese youth are also at a high risk of S&R injury.[9] The majority of injuries in youth S&R are injuries to the lower limbs (>60%), of which the majority are knee and ankle joint injuries.[3,4] The long-term effects of sport related joint injuries have been reported in numerous studies identifying reduced physical activity and post-traumatic osteoarthritis as key negative outcomes.[10-12]

The significance of the youth S&R injury burden internationally informed a focus on evidence-informed injury prevention in youth S&R as part of the IOC Consensus on Youth Athlete Development.[13] Injury prevention strategies in youth S&R include targeted rule, equipment recommendations and training strategies.[13] The majority of evaluation studies in injury prevention in youth S&R have focused on sport-specific multifaceted NMT warm-up programs (e.g., balance, strength, agility) primarily in team sports and two studies in a school physical education context.[13-26] Studies evaluating NMT strategies in youth team sport have demonstrated a preventative effect in reducing the rate of lower extremity injuries >30% and a reduction in health care costs.[13,14,17-26] In youth soccer, a 38% reduction in injury rate with a NMT program led also to an estimated $4.2M health care cost savings annually in Alberta.[26] A previous pilot cluster randomized controlled trial (RCT) evaluating a 12-week NMT warm-up strategy in junior high school physical education (PE) (n=725, ages 11-15) demonstrated the feasibility of such an RCT and a protective effect in reducing the rate of S&R injury [Incidence Rate Ratio (IRR) all injury = 0.30 (95% CI: 0.19 to 0.49), IRR lower extremity injury= 0.31 (95% CI: 0.19 to 0.51)].[17] This pilot cluster-RCT included only 2 schools and a larger cluster-RCT to further inform the protective effect of such a program was needed.

Adherence (i.e., # weeks, # sessions, # components completed) to NMT is a critical factor for intervention effectiveness across implementation contexts.[19,27-30] While most studies in youth sport have demonstrated a protective effect of NMT programs, variability in the reported effectiveness may be related to adherence.[19,27-30] A meta-analysis of the effects of NMT dose on ACL injuries found that the greater the exposure to NMT, the greater the reduction in injury.[30]

The primary objective of this cluster-RCT was to examine the effectiveness of a PE curriculum-based NMT program in reducing the rate of S&R injury (all recorded injury) in girls and boys in junior high school (ages 11-16). The secondary objectives included the effectiveness of such a program in reducing the rate of each of lower extremity injury and medical attention injury, and effectiveness in a per protocol basis. Exploratory objectives include the examination of the effectiveness of a PE curriculum-based NMT program in reducing the rate of each of S&R medical attention, knee, and ankle injuries in girls and boys in junior high school.

## Methods

### Study Design

This cluster RCT included twelve junior high schools (grades 7-9, ages 11-16) in Calgary, Alberta, Canada (2014-2017). Each participating school delivered a 12-week warm-up with a duration of 10 to 15-minutes at the beginning of their PE classes. Schools randomized to the intervention group (n=6) were asked to introduce a NMT warm-up (Appendix A), while schools randomized to the control group (n=6) were asked to carry out a standard-of-practice warm-up (Appendix B). This RCT was registered with ClinicalTrials.gov (NCT03312504).

### Recruitment

A total of 90 schools from the Calgary Board of Education (CBE) and the Calgary Catholic School District (CCSD) were eligible to participate in the study. Eligibility criteria included schools in the Calgary area with regular PE classes taught by at least one PE specialist and included grades 7-9. PE classes are mandatory in junior high school in Alberta. Students from the CBE participate in PE every day, while students from the CCSD participate in PE 2-4 times per week.

Two schools were excluded due to previous participation in a pilot study.[17] Remaining schools were randomized within East (NE and SE) and West (NW and SW) sides of the city to facilitate socioeconomic representation. Schools were recruited from CBE in years 1 and 2 and from CCSD in year 3. Schools were approached to participate in the study following a randomly generated sequence, within each of the East and West. Each study school participated in one of three years. Ethics approval was received from the University of Calgary Conjoint Health Research Ethics Board (Ethics ID REB14-0470), and both School Boards prior to commencing recruitment.

The school principal was approached by a research coordinator and invited to participate in the study followed by PE teachers. To ensure allocation concealment, teachers were recruited by the Research Coordinator prior to the study PI (CE) revealing study group assignment based on randomization. The study team attempted to recruit two classes in each of grades 7,8, and 9. Teachers who agreed to participate used the designated warm-up program with at least two PE classes in one grade. All students in the class participated in the warm-up, but data were only collected from those who returned completed parental consent and participant assent forms.

The sample size of 12 schools (6 classes, 180 students/school, 2 schools on each arm per year) was estimated based on an expected IRR of 0.3 for all reported injuries (injury rate= 3.49/1000 S&R participation hours in the control group) with an accepted Type I error of alpha=0.05 and Type II error of Beta=0.20. The sample size calculation also assumed an average class size of 30 students, 19.03 hours of exposure, a class coefficient of variation of 0.65 (planned comparison of rates controlling for cluster by class) with two classes per grade and a potential 5% dropout rate.[17]

Intervention

After recruitment into the study, school randomization allocation was revealed (intervention or control) and teachers were blinded from the details of the other group program. Teachers from both study groups attended a workshop to introduce their designated program and discuss study details. School workshops were facilitated by the Research Coordinator (Canadian Society for Exercise Physiology Certified Personal Trainer - CSEP-CPT) and the study Knowledge Broker (CSEP-CPT and teacher) from a community partner group (Ever Active Schools). The 15-minute NMT warm-up program for the intervention group included aerobic, agility, strength, and balance exercises to be delivered by the PE teacher at each PE class over the 12-week study period (see Appendix A). The intervention group workshop was based on the Health Action Process Approach (HAPA) model, and included activities aimed at fostering accurate risk perceptions and outcome expectancies, promoting task self-efficacy, and planning to maximize implementation and adherence.[30] Teachers were asked to deliver the warm-up program with participation of student leaders, facilitating correct performance of each exercise. When implementing evidence-based interventions, adaptations often occur to increase program adherence and effectiveness and this was encouraged in teacher workshop.[31] In the first year of this RCT, the Consolidated Framework for Implementation Research (CFIR) was also used to further explore facilitators and barriers to iSPRINT program implementation.[32] CFIR is composed of five major domains (i.e., intervention characteristics, individual characteristics, inner setting, outer setting, process) and 37 operationally-defined constructs that can be used to explore the contextual factors that influence intervention implementation, particularly in complex environments.[32,33] The CFIR was selected to guide the evaluation of iSPRINT because of the highly structured (school environment) yet variable nature of the implementation context.[34] The results of the CFIR study were used to continue encouragement of adaptations of iSPRINT program delivery in years 2 and 3 (e.g., modify components, sport-specific adaptation, reduce the number of components and required equipment to meet time and physical limitations).[35]

The control group warm-up was a standard-of-practice program that included aerobic, static, and dynamic stretching exercises. The teachers from the control group also attended a workshop that reviewed the standard of practice warm-up, but it did not include the HAPA model (Appendix B). Both the control and intervention group teachers were provided with teaching materials (poster and video) that included male and female youth demonstrating exercises."

Outcome Measures

An injury surveillance system initially validated in youth S&R context was used to collect baseline, exposure, and injury data.[36] This youth-based injury surveillance has been used across multiple community sports and was demonstrated to be feasible and valid for use in a junior high school physical education context in a pilot cluster-RCT study in two schools.[17] The primary outcome measure included any injuries sustained through a sport or recreational activity in or outside of school that resulted in missed time from activity participation (unable to return to the same session or prevented future activity participation) or required medical attention. A Certified Athletic Therapist provided by the study, attended each school once per week to assess any injuries the participants may have sustained over the previous week, and recorded this information in an injury report form.

At baseline, participants reported demographics, physical activity participation and S&R injuries sustained in the previous year, and concussion history on a baseline questionnaire. During the study period, participants self-reported their daily physical activity participation in weekly activity logs in class. This included categories related to active transportation, PE class and other in-school activities, out-of-school leisure time and organized sport or recreational activity participation. Teachers recorded information on warm-up adherence for each class, including individual warm-up participation (Yes or No), duration and specific exercises performed at the class level.

Statistical Analyses

Data were stored and managed using REDCap electronic data capture tools hosted at the University of Calgary.[37] REDCap (Research Electronic Data Capture) is a secure, web-based application designed to support data capture for research studies.[37] Data analyses were completed using R and Stata.[38,39]

Baseline demographics were reported (mean; SD or medians; range) for numeric variables, and frequencies and percentages for categorical variables, by study group and sex. Injury outcomes were categorized into each of all recorded injuries, lower extremity injuries, medically-treated injuries, time loss injuries (>7 days missed from physical activity participation), knee and ankle injuries. Hours of participation were imputed for participants missing physical activity exposure based on median hours by grade and/or school and/or city quadrant. If missing greater than 30% of data within group, imputation was based on the next level of data (e.g., if greater than 30% of S&R participation data were missing across a participant's grade within their school, data were imputed using the overall median within their school).

Crude rates were estimated for all injuries, lower extremity injuries and medically-treated injuries for each study group, for all participants and stratified by sex, and 95% confidence intervals were estimated considering clustering (school and class)[40] and offset by S&R participation hours. A multiple multilevel Poisson regression model was performed to estimate incidence rate ratios (IRR) [95% Confidence Intervals (95% CI)] for a primary intent to treat analysis (ITT) for all injuries [(adjusting for sex (considering interaction between sex and intervention group), previous injury; S&R participation hours was used as an offset, and school and class level random effects were examined in order to take into account the clustering at each level.]). Separate similar multiple multilevel Poisson regression models were performed for secondary ITT for lower extremity injuries and medically-treated injuries, and for secondary per protocol (minimum 2 iSPRINT warm-up sessions completed each week based on median of weekly adherence in the intervention group) analyses for all injury, lower extremity injury, and medical attention injury (these secondary per protocol included adherence as well). The IRRs are presented as the comparison between the reference group (control) and intervention group within each sex and are calculated from the models considering the interaction between sex and study group.

As exploratory analyses, for all participants for each study group, crude rates were estimated for medical attention, knee, and ankle injury, and 95% confidence intervals were estimated considering one level of clustering (school first, and if this was not significant/could not be calculated, clustering by class was considered), offset by S&R participation hours, and rate ratios were estimated with Poisson regression considering clustering effects at a school or class level (offset by S&R participation hours). For these outcomes, crude rates and rates ratios, with 95% exact CI, were estimated by sex for each study group.

Results

Twelve schools (n=1067 students representing 49 total classes) participated in this cluster-RCT (2014-2017; 4 schools per year). It is noted that all classes were mixed, including boys and girls. There were a mixture of male and female PE teachers participating in the control (10 female, 9 male) and intervention (6 female, 15 male) schools. One of the control schools completed the warm-up for only six weeks due to time constraints. Students with complete data (n=947) were included in the main multivariable analysis (Table 3). Table 1 summarizes baseline participant characteristics and Table 2 summarizes the top 10 sport and recreational activities participated in over the previous 12-months (frequencies and proportions) by sex and intervention group. Figure 1 outlines school recruitment, allocation of participants and dropouts.

Insert Table 1 here

Insert Table 2 here

Insert Figure 1 here

There were 69 S&R injuries in the control group (49 in females, 20 in males) and 54 S&R injuries in the intervention group (29 in females, 25 in males). Seven female students in the control group and 3 female students in the intervention group had multiple injuries (no males had multiple injuries). Table 3 includes the number of injuries, total hours of S&R participation exposure, and injury rates stratified by girls and boys.

Insert Table 3 here

Multiple multilevel Poisson regression analysis [(adjusting for sex (considering interaction between sex and intervention group), previous injury (no/yes), school and class as random effects, offset by S&R participation hours]) in an ITT analysis [n=947(89%) with complete covariate data], demonstrated that the intervention program was protective for all reported injury [IRR=0.543 (95% CI; 0.295,0.998)] in girls but not in boys [IRR=0.866 (95% CI; 0.425,1.766)]. The intervention program was also protective in an ITT analysis for each of lower extremity injury (only school as random effect) [IRR=0.357 (95% CI; 0.159,0.799)] and medically treated injury (only class as random effect) [IRR=0.289 (95% CI; 0.135,0.619)] in girls only [boys: IRR=1.055 (95% CI; 0.404,2.753) lower extremity injury and IRR=0.639 (95% CI; 0.266,1.532 medical attention injury] (Table 4). Based on the multivariable analyses, all participants (girls and boys) with a one-year previous injury history had a higher rate than those without injury for each of all recorded injury [IRR=2.127 (95% CI; 1.414,3.198)], lower extremity injury [IRR=1.685 (95% CI; 1.022 ,2.78)], and medical attention injury [IRR=2.896 (95% CI; 1.748,4.796)] separately.

Insert Table 4 here

For the per protocol analyses, we included only intervention participants that completed a minimum of two iSPRINT sessions per week, based on median weekly adherence from 5 intervention schools (n=396/510, 77.7%). A multivariable analyses demonstrated a similar protective effect for females and no protective effect for males (Table 5) for lower extremity and medically-treated injuries, and all participants (female and male) with a one year previous injury history were at a greater risk of each of all injury [IRR=2.15 (95% CI; 1.411, 3.275)], lower extremity injury [IRR=1.722 (95% CI; 1.029,2.884)], and medical attention injury [IRR=2.841 (95% CI; 1.698,4.751)] separately.

Insert Table 5 here

Exploratory Poisson regression analyses examining the protective effect of the iSPRINT program on each of time loss, knee and ankle injuries by sex are summarized in Table 6.

Insert Table 6 here

## Discussion

This is one of the largest cluster-RCT to examine the effectiveness of a NMT warm-up program in reducing the injury rate for each of all recorded injury, lower extremity injury and medical attention injury in schools, with a unique focus on junior high schools (ages 11-16). This cluster-RCT demonstrates a protective effect of a NMT warm-up program in reducing the rate of S&R injury in 11-16 year old female junior high school students, compared with a control warm-up, over a 12-week study period. A similar protective effect was not seen in boys.

The significantly lower rate of all injury (45.7%), lower extremity injury (64.3%), and medical attention injury (71.1%) in girls found in this study is consistent with the findings in a pilot study in the same city; however, a similar protective effect was not seen in boys.[17] The pilot study did not have the power to consider effect modification by sex.[17] The protective effect found in this study for all injury, lower extremity injury and medical attention injury in girls was similar to that previously reported in sport-specific studies.[14,19-24] Adherence in this study to the iSPRINT program was quite high with 77.7% of participants in the intervention schools participating at least two sessions per week. This may be attributed to the nature of scheduled PE class delivery in schools. The per protocol analyses does not suggest a greater protective effect when the program is delivered at least twice a week. The proportion of students in the lower adherence group was small, which might explain this finding. The adaptability of the NMT warm-up program may also have contributed to greater adherence. The exploratory analyses also suggests a potential protective effect of the iSPRINT NMT warm-up program in reducing the rate of time loss, knee, and ankle injury in female participants and timeloss and knee injuries in male participants, but these findings were not statistically significant. A larger sample size would be necessary to consider all injury outcomes. Overall, the differences found between girls and boys may be related to differences in exercise fidelity, base level of performance/neuromuscular control and/or differential reporting in girls and boys. It is noted, however, that injury follow up by school study therapists was the same for boys and girls given all classes were mixed, however it is possible that injuries not leading to time loss or medical attention may have been under-reported in boys. The lower rates of injury reported for boys across all injury definitions may also have led to a floor effect regarding the potential protective effect of NMT in male junior high school students. Future research examining iSPRINT component technique in girls compared with boys is required.

Strengths and Limitations

The strengths of this cluster-RCT include a large sample size allowing for multivariable analyses and control for known confounders, despite not meeting the desired number of students recruited in each school. Random selection of schools across multiple regions, the use of a previously validated youth community injury surveillance methodology, the collection of individual level exposure and adherence data, controlling for clustering by school and class and the focus group-informed adaptability of the intervention were all study strengths. In addition, in the first year of this study, we examined the implementation of iSPRINT in the intervention schools and the results of that study were used to inform continued adaptation of the program supported in year 1 by teachers in years 2 and 3 to maximize program adherence and effectiveness.

Limitations of this study include generalizability based on schools agreeing to participate in the study. In total, 12 of 57 schools approached agreed to participate. However, the reasons that school principals and teachers declined were based on time and school commitment to other studies and therefore may not be related to outcomes of interest. Athletic therapists recording injuries were present in each school once per week. This may have led to an under-reporting of injuries; however, this was present for both intervention and control schools and may have led to underestimation of the effect found. The generalizability of these findings outside of an urban region is unknown.

Exposure to S&R participation was calculated based on students' responses to weekly questionnaires and these data may be subject to recall bias. Adherence in reporting exposure was 74.7% in the intervention group and 57.1% in the control group. In total, 33.6% of all exposure data were imputed.

Randomization was at the level of the school effectively producing only 12 randomization units with the potential for confounding by unmeasured cluster level factors. However, the effective sample size of units at which the intervention was aimed and at which analysis was performed was 1067 (students) and the sample size calculation was based on a class coefficient of variation of 0.65. The schools were reasonably well balanced on the key characteristics (table 1), and we adjusted for these potential confounding variables in our analysis. We also randomized within east and west sides of the city which would, in admittedly a relatively crude way, balance some aspects of socioeconomic status across the intervention-control contrast.

## Conclusion

A NMT warm-up program in junior high school (ages 11 – 16) PE classes was effective in preventing S&R injury including each of all injuries, lower extremity injuries, and medically treated injuries separately in female students. A similar protective effect was not found in males. Future research should consider economic evaluation of the iSPRINT NMT warm-up program and consideration of mechanisms that may explain differences in the protective effect of such a program between girls and boys.

**Competing interests**

The authors of this work have no competing interests to report.

**Contributorship**

CAE, SAR, LPD, CDM, PKDB, ANA, EV, KB, AM, and BEH contributed to the study proposal development. CvdB and LPD contributed to data collection, entry, and data cleaning. CAE, CvdB, LPD, ANA, and BEH contributed to the data analysis and interpretation of study results. CAE, SAR, LPD, CDM, PKDB, ANA, EV, AM, and BEH contributed to acquisition of funding and study design. CAE and BEH led all aspects of the cohort. All authors critically reviewed and edited the manuscript before submission.

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**Ethical approval information**

Ethics approval was received from the University of Calgary Conjoint Health Research Ethics Board (Ethics ID REB14-0470), and both School Boards prior to commencing recruitment.

**Data sharing statement**

Data sharing is not applicable for this study.

**Patient involvement**

Yes

Ever Active Schools was involved as the knowledge broker community partner in contributing to approval of study design, study recruitment, injury surveillance methods, development of intervention and control group programs, support of school-based therapist role and dissemination of research findings within the school community. The research questions and outcome measures were developed and informed by the priorities, experience, and preferences of Ever Active Schools, Calgary Board of Education and Calgary Catholic School Board. Junior High School Students, parents, teachers and administrators in the Calgary Board of Education and Calgary Catholic School Board were dedicated to the collection of weekly exposure data, identification of a student with a suspected injury, and supporting communication with the research team for injury follow-up. A knowledge broker from Everactive Schools (MM) informed the methods and time commitment for study participation by students and parents and teachers. Partners from Ever Active Schools, Calgary Board of Education and Calgary Catholic School Board have received an executive report of the study findings based on preliminary results and abstract presented at the Canadian Academy of Sport and Exercise Medicine (2018) and will inform dissemination of final study results in the school community once the final manuscript results are published. The Injury Prevention Centre and the Sport Injury Prevention Research Centre will contribute to evidence informed safety guideline updates for Alberta Schools.

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Table 1: Baseline characteristics by sex and study group (n=1,067)

| Covariate | | Girls | | Boys | |
|---|---|---|---|---|---|
| | | Intervention (n=281) | Control (n=292) | Intervention (n=285) | Control (n=209) |
| Age<br>(yrs) (median; range)<br>missing | | 13 (11-15)<br>n=9 (3.2%) | 13 (11-16)<br>n=18 (6.2%) | 13 (11-16)<br>n=7 (2.5%) | 13 (11-15)<br>n=16 (7.7%) |
| Grade<br>n (%) | 7 | n=108 (38.4%) | n=128 (43.8%) | n=123 (43.1%) | n=94 (45.0%) |
| | 8 | n=94 (33.5%) | n=85 (29.1%) | n=76 (26.7%) | n=59 (28.2%) |
| | 9 | n=79 (28.1%) | n=79 (27.1%) | n=86 (30.2%) | n=56 (26.8%) |
| Height<br>(cm) mean (sd)<br>missing | | 158.1 (7.5)<br>n=18 (6.4%) | 158.7 (7.4)<br>n=34 (11.6%) | 161.9 (10.9)<br>n=25 (8.7%) | 162.2 (10.2)<br>n=18 (8.6%) |
| Weight<br>(kg) (median; range)<br>missing | | 49.3 (29.4-105.2)<br>n=20 (7.1%) | 49.6 (28.9-89.0)<br>n=46 (15.8%) | 52.4 (24.7-108.8)<br>n=24 (8.4%) | 50.1 (30.3-103.1)<br>n=23 (11.0%) |
| Waist circumference<br>(cm) (median; range)<br>missing | | 66.8 (51.3-111.5)<br>n=25 (8.9%) | 68 (52.9-107.5)<br>n=50 (17.1%) | 70.0 (51.0-119.9)<br>n=29 (10.2%) | 69.0 (54.0-108.5)<br>n=24 (11.5%) |
| BMI<br>($kg/m^2$)(median; range)<br>missing | | 19.7 (13.6-37.5)<br>n=20 (7.1%) | 19.4 (14.0-32.3)<br>n=47 (16.1%) | 19.4 (13.2-40.4)<br>n=25 (8.7%) | 18.9 (12.6-31.5)<br>n=23 (1.0%) |
| Previous sport/recreational injury - 1 year (%)<br>missing | | n=179 (63.7%) No<br>n=67 (23.8%) Yes<br>n=35 (12.5%) | n=192 (65.8%) No<br>n=66 (22.6%) Yes<br>n=34 (11.6%) | n=204 (71.5%) No<br>n=52 (18.3%) Yes<br>n=29 (10.2%) | n=159 (76.1%) No<br>n=28 (13.4%) Yes<br>n=22 (10.5%) |

Table 2 Top 10 sport and recreational activities participated in over the previous 12-months (frequencies and proportions) by sex and intervention group

| Females | | | | Males | | | |
|---|---|---|---|---|---|---|---|
| Intervention (n=281) | | Control (n=292) | | Intervention (n=285) | | Control (n=209) | |
| Swimming | 76 (27.046) | Swimming | 89 (30.479) | Basketball | 67 (23.509) | Swimming | 49 (23.445) |
| Running | 28 (17.082) | Dance | 56 (19.178) | Swimming | 65 (22.807) | Soccer | 45 (21.531) |
| Volleyball | 43 (15.302) | Badminton | 52 (17.808) | Soccer | 59 (20.702) | Basketball | 43 (20.574) |
| Soccer | 39 (13.879) | Volleyball | 51 (17.466) | Running | 47 (16.491) | Cycling | 42 (20.096) |
| Basketball | 37 (13.167) | Basketball | 50 (17.123) | Badminton | 41 (14.386) | Badminton | 41 (19.617) |
| Dance | 35 (12.456) | Cycling | 47 (16.096) | Cycling | 41 (14.386) | Ice hockey | 35 (16.746) |
| Cycling | 30 (10.676) | Running | 42 (14.384) | Ice hockey | 29 (10.175) | Running | 26 (12.440) |
| Badminton | 28 (9.964) | Soccer | 39 (13.356) | Volleyball | 27 (9.474) | Football | 22 (10.526) |
| Hiking and Scrambling | 24 (8.541) | Hiking and Scrambling | 32 (10.959) | Floor hockey | 25 (8.772) | Field hockey | 21 (10.048) |
| Martial arts | 18 (6.406) | Alpine skiing | 27 (9.247) | Football | 25 (8.772) | Hiking and Scrambling | 21 (10.048) |

**Table 3:** Injury incidence crude rates by injury type for all participants, girls, and boys, (95% CI considered cluster by class and school†) (n=1,067)

| | | All injuries | | Lower extremity injuries | | Medically-treated injuries | |
|---|---|---|---|---|---|---|---|
| | | Control | Intervention | Control | Intervention | Control | Intervention |
| No. students | All | 501 | 566 | 501 | 566 | 501 | 566 |
| | Girls | 292 | 281 | 292 | 281 | 292 | 281 |
| | Boys | 209 | 285 | 209 | 285 | 209 | 285 |
| No. hours | All | 33423.6 | 36565.6 | 33423.6 | 36565.6 | 33423.6 | 36565.6 |
| | Girls | 18794.1 | 17616.2 | 18794.1 | 17616.2 | 18794.1 | 17616.2 |
| | Boys | 14629.5 | 18949.4 | 14629.5 | 18949.4 | 14629.5 | 18949.4 |
| No. injuries | All | 69 | 54 | 51 | 35 | 49 | 24 |
| | Girls | 49 | 29 | 40 | 18 | 37 | 13 |
| | Boys | 20 | 25 | 11 | 17 | 12 | 11 |
| Injury rate (No. injuries/1000 hours) (95% CI) | All | 2.064 (0 , 4.537) | 1.477 (0 , 3.476) | 1.526 (0 , 4.279)* | 0.957 (0 , 3.042)* | 1.466 (0 , 3.7) | 0.656 (0 , 2.086 |
| | Girls | 2.607 (0.015 , 5.2) | 1.646 (0 , 3.774) | 2.128 (0 , 4.911) | 1.022 (0 , 3.013) | 1.969 (0, 4.661)* | 0.738 (0 , 2.44)* |
| | Boys | 1.367 (0 , 3.536)* | 1.319 (0 , 3.192)* | 0.752 (0 , 2.781)* | 0.897 (0 , 2.844)* | 0.820 (0 , 1.933) | 0.580 (0 , 1.403) |

CI: confidence interval

†In cases where both random effects were able to be calculated and/or were significant, both appeared, unless otherwise mentioned

*Only cluster by school

**Table 4:** Injury incidence rate ratios based on intent to treat multiple multilevel Poisson regression analyses† by injury type for all participants with complete covariate data (n=947).

| | | All injuries<br>IRR (95% CI) | Lower extremity injuries<br>IRR (95% CI)* | Medically-treated injuries<br>IRR (95% CI)** |
|---|---|---|---|---|
| Girls | Control | Reference | Reference | Reference |
| | Intervention | 0.543 (0.295 , 0.998) | 0.357 (0.159 , 0.799) | 0.289 (0.135 , 0.619) |
| Boys | Control | Reference | Reference | Reference |
| | Intervention | 0.866 (0.425 , 1.766) | 1.055 (0.404 , 2.753) | 0.639 (0.266 , 1.532) |
| Previous injury | No | Reference | Reference | Reference |
| | Yes | 2.127 (1.414 , 3.198) | 1.685 (1.022 , 2.78) | 2.896 (1.748 , 4.796) |

CI: confidence interval

IRR: Incidence rate ratio

†[Multiple multilevel Poisson regression analyses (adjusting for sex (considering interaction between sex and intervention group), previous injury, offset by S&R participation hours]. In cases where both random effects were able to be calculated and/or were significant, both appeared, unless otherwise mentioned. IRRs have been calculated to consider comparison of control and intervention group within sex

*Only school random effect**Only class random effect

**Table 5:** Injury incidence rate ratios based on per protocol [including only intervention participants completing a minimum of two iSPRINT sessions per week based on median weekly adherence and all control schools (n= 444 females, n=362 males)] multiple multilevel Poisson regression analyses† by injury type for all participants with complete covariate data (n=806).

| | | All injuries IRR (95% CI) | Lower extremity injuries IRR (95% CI)* | Medically-treated injuries IRR (95% CI)** |
|---|---|---|---|---|
| Girls | Control | Reference | Reference | Reference |
| | Intervention | 0.611 (0.334 , 1.119) | 0.416 (0.188 , 0.922) | 0.317 (0.141 , 0.710) |
| Boys | Control | Reference | Reference | Reference |
| | Intervention | 0.962 (0.461 , 2.009) | 1.122 (0.419 , 3.004) | 0.786 (0.316 , 1.958) |
| Previous injury | No | Reference | Reference | Reference |
| | Yes | 2.15 (1.411 , 3.275) | 1.722 (1.029 , 2.884) | 2.841 (1.698 , 4.751) |

CI: confidence interval

†[Multiple multilevel Poisson regression analyses (adjusting for sex (considering interaction between sex and intervention group), previous injury, offset by S&R participation hours]. In cases where both random effects were able to be calculated and/or were significant, both appeared, unless otherwise mentioned. IRRs have been calculated to consider comparison of control and intervention group within sex

*Only school random effect

**Only class random effect

**Table 6** Exploratory injury incidence rates and rate ratios (with 95% CI) based on intent to treat Poisson regression analyses by injury type for all participants and by sex (n=1,067)

| | | Time loss injuries | | Knee injuries | | Ankle injuries | |
|---|---|---|---|---|---|---|---|
| | | Control | Intervention | Control | Intervention | Control | Intervention |
| No. students | All | 501 | 566 | 501 | 566 | 501 | 566 |
| | Girls | 292 | 281 | 292 | 281 | 292 | 281 |
| | Boys | 209 | 285 | 209 | 285 | 209 | 285 |
| No. hours | All | 33423.6 | 36565.6 | 33423.6 | 36565.6 | 33423.6 | 36565.6 |
| | Girls | 18794.1 | 17616.2 | 18794.1 | 17616.2 | 18794.1 | 17616.2 |
| | Boys | 14629.5 | 18949.4 | 14629.5 | 18949.4 | 14629.5 | 18949.4 |
| No. injuries | All | 10 | 7 | 16 | 8 | 17 | 15 |
| | Girls | 6 | 3 | 12 | 4 | 14 | 9 |
| | Boys | 4 | 4 | 4 | 4 | 3 | 6 |
| Injury rate (No. injuries/1000 hours) (95% CI) | All† | 0.299<br>(0,1.108)* | 0.191<br>(0,0.81)* | 0.479<br>(0,1.484)** | 0.219<br>(0,0.869 )** | 0.509<br>(0,2.01 )* | 0.41<br>(0,1.699)* |
| | | IRR= 0.643 (0.238 ,1.735)* | | IRR= 0.48 (0.17,1.356 )** | | IRR=0.732(0.307,1.745)* | |
| | Girls ‡ | 0.319<br>(0.117,0.695) | 0.17<br>(0.035,0.498) | 0.638<br>(0.33,1.115) | 0.227<br>(0.062,0.581) | 0.745<br>(0.407,1.2) | 0.511<br>(0.234,0.97) |
| | | IRR= 0.533 (0.086,2.498 ) | | IRR= 0.356 (0.084,1.173) | | IRR= 0.686 (0.262,1.701) | |
| | Boys ‡ | 0.273<br>(0.074,0.7) | 0.211<br>(0.058,0.54) | 0.273<br>(0.074,0.7) | 0.211<br>(0.058,0.54) | 0.205<br>(0.042,0.599) | 0.317<br>(0.116,0.689) |
| | | IRR= 0.772 (0.144, 4.145) | | IRR= 0.772 (0.144, 4.145) | | IRR= 1.544 (0.33, 9.542) | |

CI: confidence interval

IRR: incidence rate ratio

† Crude rates with 95% confidence intervals considering one level of clustering (school first, and if this was not significant/could not be calculated, clustering by class was considered), offset by S&R participation hours. Rate ratios were estimated with Poisson regression considering clustering effects at a school or class level (offset by S&R participation hours)

*School random effect

**Class random effect

‡ Crude rates and rates ratios, with 95% exact CI