iSPRINT – Implementing a school prevention program to reduce injuries through neuromuscular training

1. Purpose

In a pilot randomized controlled trial (RCT), we demonstrated that a curriculum-integrated neuromuscular training (NMT) intervention with a moderate to high intensity component, delivered as a warm-up to physical education class, reduced injury risk by 50%, improved cardiovascular fitness, and decreased measures of adiposity in junior high school students (aged 11-15)[1]. This pilot, cluster RCT involved only two schools (n=1412); as such the ability to appropriately adjust for cluster design was not possible. In the current study, an evidence-informed, injury prevention program is being implemented and will be evaluated on a larger scale in Alberta's physical education curriculum. The focus of this research is to evaluate the effectiveness of the injury prevention program among junior high school students in Alberta, including optimization of the implementation context to facilitate adherence and maintenance of such a program provincially.

2. Context

Sport and recreation (S&R) participation are extremely important to maintain a healthy lifestyle. Childhood physical activity promotes healthy growth and development and prevents chronic disease[2]. The proportion of obese children has tripled over the past 25 years in Canada[2]. While we strive for an active population, participation in any physical activity must consider the risk of injury and measures for injury prevention. Sport and recreation is the leading cause of injury in youth. Each year, an estimated 35% of youth in Alberta sustain a S&R related injury requiring medical attention[3,4].

It has been well established that age, sex and previous injury are independent risk factors for sustaining a sport related injury[5]. Much of the existing literature addressing S&R injury risk among youth is sport-specific, and research addressing body composition as a modifiable risk factor for S&R injury in children and adolescents is only beginning to emerge[6–8]. Retrospective studies of socio-demographic risk factors among Alberta students have demonstrated that youth with high body mass index (BMI) scores (i.e. tendency towards overweight) are at a significantly higher risk of S&R injury compared with those with lower BMI scores (i.e. tendency towards healthy body shape)[8,9]. A program that has the potential to demonstrate effectiveness in decreasing injury risk, while also improving healthy outcomes, would have significant public health impact. Measures of body composition such as BMI and waist circumference, as well as fitness measures of aerobic capacity and muscular strength, are some of the healthy outcomes, which can be evaluated over a period of time to determine maintenance or an improvement of one's health.

Research has established that the lower limb, particularly the ankle and knee, are common sites for musculoskeletal injuries for junior high students, accounting for >60% of S&R injuries[4]. This is consistent with research of most common injured body regions

among other populations[3,10–13]. Injuries to these two joints increase an individual's risk of developing early-onset osteoarthritis[14], which subsequently creates a burden on society, through direct costs (e.g., medical care and expenses) and indirect costs (e.g., quality of life and wellness)[15–19]. Injuries sustained through S&R participation can deter or prevent future involvement in physical activity, which can create a burden on the public health system through the increased risk of sedentary, degenerative, and lifestyle ailments such as diabetes, obesity, certain cancers and cardiovascular conditions [20–25].

Previous studies in youth soccer and basketball have established the effectiveness of sport-specific NMT warm-up programs at reducing the risk of injury[12,13,26–30]. The degree of protection any given NMT program might have on an individual is often attributed to the level of adherence, or regularity of completing the exercises[10,12,31]. A major benefit to the proposed research is that implementing a NMT injury prevention program within schools, as part of a structured class setting, will likely correspond with high individual adherence to the program, provided teachers responsible for delivering the program ensure regular and correct program execution. Additionally, the intervention program has a component of high intensity exercise, which may improve healthy outcomes among students, such as BMI, as well as lower the risk of S&R injury.

3. Objectives

Primary

1. To determine whether a curriculum-integrated NMT program is effective at reducing the risk of S&R injury in junior high school students.
2. To determine whether a curriculum-integrated NMT program is effective at improving healthy outcome measures in junior high school students.

Secondary

1. To determine the cost-effectiveness of implementing a NMT program in junior high schools.
2. To determine the effectiveness of the Health Action Process Approach (HAPA) to implementation in maximizing adherence and maintenance of this program beyond program implementation.

4. Approach

4.1 Study Design

A randomized controlled trial (RCT)is currently being implemented (year 2 of 3). During the first year (2014-2015 school year), two schools received a control warm-up program and two schools received the intervention warm-up program. A workshop is delivered to teachers from each school on the implementation of the warm-up program**.** Health and physical fitness measurements are taken at baseline and again at follow-up to assess changes in healthy outcomes.

4.2 Recruitment

Junior high schools in Calgary from the Calgary Board of Education are approached to participate in the study. The goal is to have two schools participating each year from the Western side of Calgary and two schools from the Eastern side.Schools that meet the inclusion and exclusion criteria are randomly approached for participation. The study research coordinator approaches the schools and has a meeting with the school principal to discuss the study. If the school principal agrees to allow the school to participate, the research coordinator returns to the school for another visit to discuss the study with the physical education (PE) teachers, who ultimately decide whether or not their classes will be included in the study.

Inclusion criteria for schools:

1. Junior high schools with a minimum of three PE classes per week
2. PE classes that are taught or co-taught by a PE specialist

Exclusion criteria for schools:

1. Schools that are culturally distinct (e.g., aboriginal perspective teaching)
2. Single-sex schools (i.e. boys' or girls' schools)
3. Schools that cater to students with special needs (e.g., behavioural and emotional programs)
4. Schools with incomplete grades (i.e., do not have all three junior high grades 7, 8, and 9)
5. Schools located outside of a 20-km radius of the University of Calgary

During the first year of the study, 20 schools were approached in Western Calgary; 16 declined, 2 did not respond, and 2 agreed to participate. Nine schools were approached in the East; 6 declined, 1 did not respond, and 2 agreed to participate. School study recruitment for year 1 is summarized in Figure 1.

Once a school agrees to participate, the research coordinator approaches the classes and provides the students with information about the study. Students receive a package to take home to their parents, which includes a consent form, an assent form, a Physical Activity Readiness Questionnaire for Everyone (PAR-Q+), and questionnaires that collect information on baseline data. These include a baseline questionnaire, a Euro-Quality of life questionnaire for youth (EQ-5DY), and a questionnaire asking about current knowledge and beliefs of S&Rinjuries and injury prevention. Participants who return their completed consent and assent forms are included in the study. Students who meet the inclusion and exclusion criteria will be included in the final analysis.

Inclusion criteria for participants:

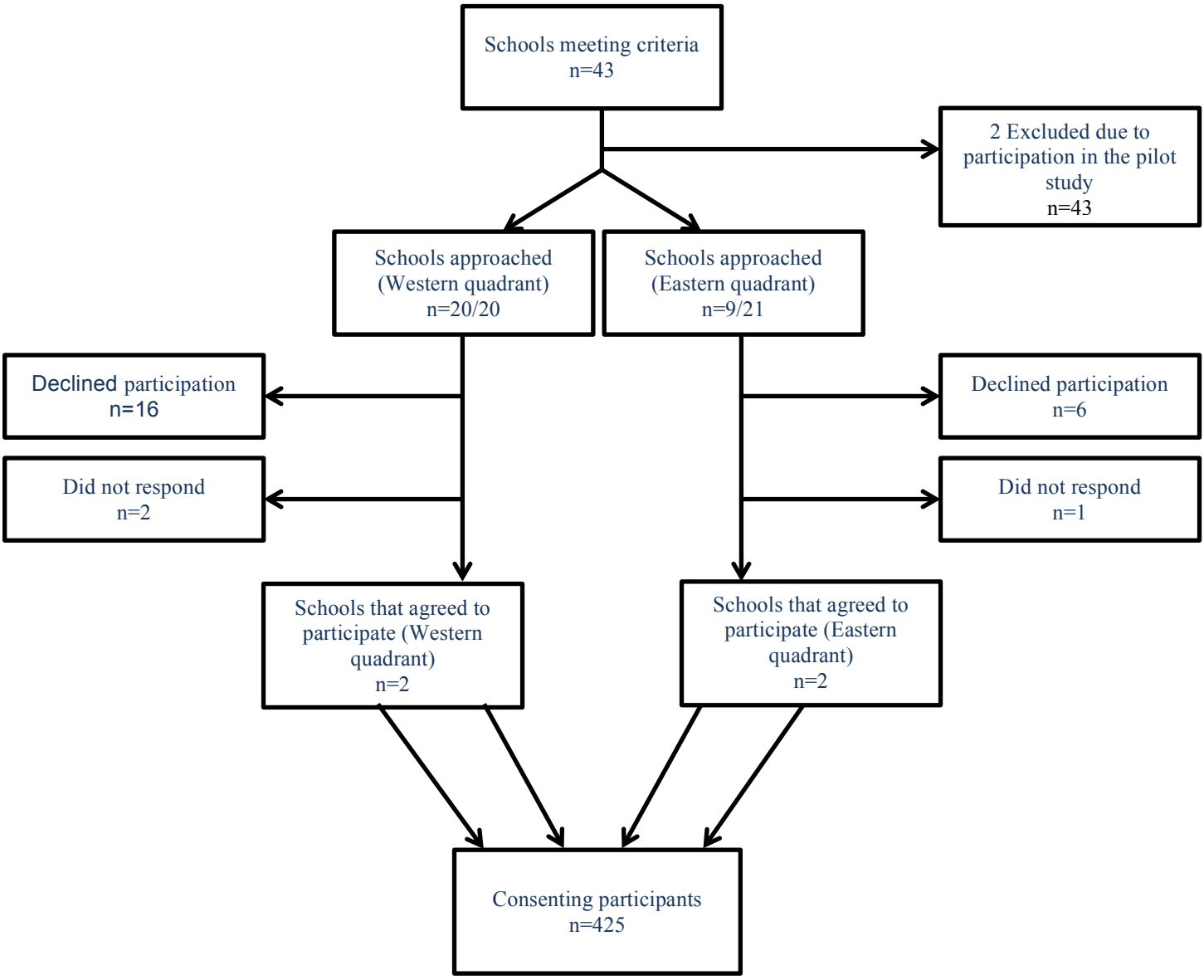
1. Students fully participating in the PE curriculum at baseline.
2. Students who return completed assent and parental consent forms.

Exclusion criteria for participants:

1. Recent history of musculoskeletal disorders (e.g., currently rehabilitation from a recent fracture, rheumatologic condition, neurological condition, systemic disease

or surgery) or medical condition that prevents participation in a regular PE curriculum (e.g., recurrent fainting or dizzy spells, hypertension).

Figure 1. School recruitment



4.3 Workshop

A workshop is delivered to the teachers after the baseline testing (described in Section 4.5.1) to inform the teachers about the warm-up program. This workshop includes a presentation that addressesS&R injuries and injury prevention. The control group receives instruction and demonstrations on components of their designated warm-up program, while the intervention group watches a video on the warm-up program. The workshop delivered to the intervention group is modelled using theHealth Action Process Approach (HAPA), and also includes a group discussion to brainstorm strategies on program implementation as well as time to practice the warm-up components. The knowledge broker from Ever Active Schools is engaged in all of the workshops to provide support to the teachers on the delivery of the program.

4.4 Program

Initially, the warm-up program was designed to be implemented for four months (16 weeks). In the first year of the study, due to the delay in schools agreeing to participate, the intervention period was decreased from four months to three months (12 weeks), which was necessary to fit the required data collection within the school year, prior to the end of school in June 2015. This was consistent with the methods of the pilot RCT and allows these data to be combined for analyses.

4.4.1 Intervention

The warm-up program used as the intervention is based on the FIFA 11+, which is a 20-minute warm-up program designed to reduce injuries in male and female soccer players. Teams who performed this program demonstrated a significantly lower risk of lower extremity injuries compared with a control program that consisted of the team's regular (i.e., standard of practice) warm-up[31].

The intervention warm-up program consists of 15 exercises that are divided into aerobic components, strengthening components, and balance components.

1. Aerobic components
    a. Forward running
    b. Forward running with skipping
    c. Forward running with knee lifts
    d. Forward running with heel kicks
    e. Sideways shuffles
    f. Zigzag running
    g. Forward running with intermittent stops
    h. Speed runs
    i. Jumping
2. Strengthening components
    a. Plank
    b. Side plank
    c. Hamstrings
    d. Lunges
3. Balance components

a. Wobble board
b. Balance pad

All strengthening and balance components, as well as the jumping component, include levels for progression. The program has been adapted for use in schools (i.e., the suggested running distance for each aerobic component is two laps around the gym).

4.4.2 Control

The control program also consists of 15 exercises that are divided into aerobic and stretching components.

1. Aerobic components
    a. Forward running
    b. Forward running with arm swings
    c. Forward running with side shuffles
    d. Lunging
    e. Low skipping
    f. Forward running with arm swings
    g. Forward running (cool-down)
2. Stretching components
    a. Standing quadriceps stretch
    b. Standing hamstring stretch
    c. Standing calf stretch
    d. Standing groin stretch
    e. Rotating ankle
    f. Standing shoulder stretch
    g. Standing triceps stretch
    h. Standing neck stretch

Teachers are asked to implement the warm-up program for 12 weeks. The fourth school that was recruited in year one of the study (control school) was only able to implement their warm-up program for 6 weeks due to time constraints.

4.5 Measures

4.5.1 Baseline

The baseline questionnaireis sent home in the participant study package with the consent/assent forms and a PAR-Q+ form. Participants complete the baseline questionnaire with the help of their parents if needed. The baseline questionnaire asks about demographic information, physical activity participation over the previous 12 months (including active transport, physical activity during school, and leisure time physical activity), medical history including injuries, and health care utilization in the previous 12 months. The PAR-Q+ form is used to determine if a participant is safe to participate in the 20-m shuttle run test as part of the study baseline assessments. Upon returning completed consent forms, students participate in baseline testing, which is held on-site at the junior high schools over a period of two PE classes. During this time,

participants also complete a Knowledge and Beliefs (K&B) questionnaire and the EQ-5DY. The K&B questionnaire contains questions on current knowledge and beliefs of injury risk and prevention, while the EQ-5DY is used to assess an individual's health using a descriptive profile and a single index value.

For the physical baseline measurements, students are divided into two groups; one completes the PACER 20-m shuttle run, and the other completes health and musculoskeletal measures, including height, weight, waist circumference, leg length, vertical jump test, star excursion balance test, and unipedal timed dynamic balance on a foam pad. On the second day of testing, the groups switch. This is done to ensure that fatigue from the 20-m shuttle run does not influence vertical jump or balance tests.

Teachers complete a consent form and their version of the K&B questionnaire before receiving the workshop. Teachers who receive the intervention workshop complete a fidelity check immediately following the workshop.

4.5.2 Six-week follow-up

Six weeks after beginning the warm-up program, the students and teachers complete the K&B questionnaire again to assess if their knowledge and beliefs on injury prevention changed halfway into the program.

4.5.3 Injury reporting

Each school is assigned a study athletic therapist, who attends the school one day per week throughout the duration of the program to assess any injuries sustained by the study participants. If a participant sustains an injury, they are encouraged to identify themselves to their PE teacher or to the study athletic therapist, who provides them with an injury report form. The participant fills out the first page of this report form, which collects information about the details of the injury such as the date that the injury was sustained, location of injury, sport or activity at the time of injury. The athletic therapist then completes a physical assessment on their injury and completes the remainder of the injury report form. They also provide the participant with exercises to help rehabilitate their injury.

4.5.4 Exposure data

Throughout the duration of the program, teachers are asked to report PE warm-up program adherence by recording the program exercises that are completed each class, and which students participate in the warm-up (fully, partially, or not at all). In some schools, teachers nominate a student designate to complete these sheets.

Students also complete physical activity journals each week, where they report the frequency, intensity, duration, and type of activity during the week for leisure time activity, PE class, activities outside of school, and active transport.

4.5.4.1 Validation of PE warm-up program adherence

At each of the participating schools in the first year of the study, one of the Master's students (Rebecca Carnduff or Carla van den Berg) attended three of the PE classes in each school to observe the warm-up for all of the classes participating in the study. This was done to ensure that the daily exposure sheets of the program completed by the teachers or by a student designate were accurate.

4.5.4.2 Validation of student weekly physical activity exposure

During the first year, students at two of the schools were invited to participate in a validation study, where they wore a Garmin Vivofit and an Actigraph accelerometer to track their physical activity over the course of one week. Nineteen students from each of the two schools were randomly selected to participate. The purpose of this was to validate the weekly physical activity journals to the Actigraph accelerometers, as well as to compare the commercially available physical activity tracking tool (Garmin Vivofit) to the validated accelerometer tool.

5. Results

This is a four-year study in which only the first year has been completed; therefore, final results are not reported in this scientific report. Data from year one is in the process of being entered, therefore this results section is limited to the data available to-date. Results reported in this section include preliminary baseline characteristics (Table 1) and baseline measures (Table 2), and results from the MSc student (Carla van den Berg) thesis looking at baseline measures using a cross-sectional design.

5.1 Participants

From the 4 junior high schools included in the study, 425 participants consented to participate. This included 95 students from the first school that was recruited (intervention school; 58% consent rate), 97 participants from the second school (control school; 54% consent rate), 148 participants from the third school (intervention school; 69% consent rate), and 91 participants from the fourth school (control school, 54% consent rate). Baseline characteristics are reported in Table 1.

Table 1. Participant baseline characteristics

		Intervention (n, %) (n=250)		Control (n=192)	
Grade	7	99	(39.6%)	82	(42.7%)
	8	65	(26.0%)	55	(28.6%)
	9	86	(34.4%)	55	(28.6%)
	Missing	0		0	
Sex	Male	99	(39.6%)	61	(31.8%)
	Female	108	(43.2%)	83	(43.2%)
	Missing	43	(17.2%)	48	(25.0%)

5.2 Baseline characteristics

Preliminary results for the baseline characteristics are included below. Note that data entry is still in process and the data have not yet been cleaned. Table 2 includes means (95% CI) of each of the baseline health and physical fitness assessments for the intervention and control schools.

Table 2. Baseline health and physical fitness measures

Characteristic	Intervention (n=243) Mean (95% CI)	Control (n=185) Mean (95% CI)
Height (cm)	160.6 (159.4, 161.8)	160.2 (158.9, 161.5)
Weight (kg)	53.2 (51.4, 54.9)	51.5 (49.7, 53.2)
BMI (kg/m^2)	20.4 (19.8, 20.9)	19.8 (19.2, 20.4)
Waist circumference (cm)	73.2 (68.2, 78.2)	72.4 (67.1, 77.6)
PACER 20-m shuttle run (stage)	36 (33, 38)	41 (38,44)
Foam pad balance, Right (sec)	8.2 (7.2, 9.1)	8.6 (7.7, 9.5)
Foam pad balance, Left	8.5 (7.4, 9.6)	8.7 (7.4, 10.0)
Star excursion balance test normalized composite reach distance, Right (%)	77.5 (75.9, 79.2	77.7 (75.9, 79.5)
Star excursion balance test normalized composite reach distance, Left (%)	78.2 (76.6, 79.7)	79.0 (77.4, 80.7)
Vertical jump height (cm)	34.0 (32.5, 35.6)	34.7 (33.4, 35.9)

5.3 MSc project

One of the MSc students working on the project (Carla van den Berg) defended her thesis, entitled 'The influence of previous injury history on health and fitness outcomes in junior high school students' in October 2015. This thesis focused on the data collected at baseline in the four schools in year one of the study, in addition to the two schools that participated in the pilot project during the 2008-2009 school year. Using the injury information collected from the baseline questionnaire regarding previous S&R injury history and the health and fitness measurements taken at baseline, the main results found that those who had sustained a previous S&R injury had significantly better predicted VO_2max scores (β=2.31, 95% CI 1.18, 3.44 mL/kg/min, $p<0.001$) based on the 20-m shuttle run, significantly better logarithmically transformed left foot dynamic balance times on the foam pad (β=0.154, 95% CI 0.046, 0.262, p=0.005), and significantly higher BMI z-scores(β=0.294, 95% CI 0.121, 0.468, p<0.001) compared with participants with no history of S&R injury within the previous year. The log odds of having a BMI that classified participants as overweight or obese were significantly increased in the previously injured group compared with the uninjured group (OR=1.82, 95% CI 1.21, 2.74).The median weekly hours of sport participation were approximately two hours higher in the previously injured group compared with the uninjured group. No significant differences in vertical jump height, star excursion balance test reach distances, or right foot dynamic balance times were demonstrated between injury groups.

6. Knowledge Translation Activities

Integrated knowledge translation and continuous stakeholder engagement are key facets of this study. As part of the Alberta Program in Youth Sport & Recreational Injury Prevention, of which this study is one component, a knowledge broker has been selected

from Ever Active Schools (EAS). EAS is the main community partner involved in this study. As part of their mandate, EAS "facilitates the development of health children and youth by fostering social and physical environments that support health, active school communities". The establishment of a formal collaboration with EAS has demonstrated itself to be an excellent way for our research team to gain valuable insight on aspects of the school environment, study feasibility and logistics. Our collaboration with EAS has already proven to be mutually beneficial. For example, we have been able to provide EAS with resources regarding injury prevention and have been invited to deliver various talks to share evidence-based information to EAS schools and partners.

The knowledge broker (Megan McKinley) plays a very active role in the project. The knowledge broker is involved in both strategic planning and day-to-day project activities including: liaising with Calgary Board of Education or school personnel, helping to develop the workshops and NMT program elements, providing input on the study design and methods including feasibility, recruitment, data collection, workshop delivery and follow-up.

Moving forward the knowledge broker model will be used to inform future projects and similar collaborations. This type of formal collaboration may be expanded to other organizations (e.g., Alberta Athletics, Be Fit For Life) either in the context of the current study or other opportunities.

7. Further Research

This section will comment on the next steps for the study, particularly focusing on year two.

7.1 Maintenance schools

One of the four schools from year one agreed to participate in the study for a second year. As this school followed the intervention program in their first year, they continue to do so in the second year of the study and are considered a 'maintenance' school. The teachers at the maintenance school voiced that they wanted to continue delivering certain components of the intervention warm-up program in year two, but would also wanted to include some of their own components. The study design is consistent in year two for the maintenance school, in that all assessments are included again. Healthy outcomes and physical fitness measures will be taken at baseline and follow-up, a study athletic therapist is assigned to the school to assess any injuries, and students will fill out their physical activity exposure data.

In future years, any school assigned to the control arm of the study who agrees to participate in the study for a subsequent year will be asked to participate in the intervention warm-up program (i.e., cross-over).

7.2 Year 2 new school recruitement

The goal for the 2015-2016 school year is to recruit four new schools to participate in the study; two will receive the control warm-up program and two will receive the intervention warm-up program. As of November 2015, three schools have

confirmed participation. One of these schools completed baseline testing in September 2015, and was randomly assigned to the intervention arm of the study. The workshop was delivered to the five PE teachers, and the teachers have been delivering the program to their students for seven weeks. The remaining two schools have not yet been assigned to a control or an intervention arm, as they have not yet completed baseline testing. One school has confirmed that they will start the program delivery by the week of December 7th, and the other school has confirmed they will start the program delivery by the week of January 18th.

An additional four schools will be recruited in each subsequent year (four schools will be recruited in year three and four schools will be recruited in year four), bringing the total number of schools over four years to 16 schools. Data will continue to be collected on any school that agrees to remain in the study for a second year.

7.3 Focus Groups

Moving forward into the second year of the study, focus groups will be held with students and teachers who are involved in the intervention group. These focus groups will be used to gather information regarding how schools and school boards can identify and package sport injury prevention evidence into a practical and useful curriculum, in addition to understanding the political and social context in which these programs are implemented, adopted, and maintained beyond one school year. A few students will be nominated from each grade to participate in the focus groups. Teachers will help select which students should be invited to participate based on their engagement in the class, in order to ensure a broad range of students are included in these groups (i.e., some students who are very engaged in the program and some who are not). Teachers will also be involved in the focus groups.

7.4 Trainees

Dr. Oluwatoyosi Owoeye (post-doctoral fellow) has been cleaning and analyzing quantitative and qualitative data of an end-of-study questionnaire designed using the RE-AIM (Reach, Efficacy, Adoption, Implementation, Mainentance: www.re-aim.org) framework that was administered to both participating students and teachers upon first year study completion. The results of these questionnaires will inform questions to be used in focus groups that we are planning to use in years 2 and 3 of the study.

Rebecca Carnduff (MSc student) led data cleaning and the preliminary analysis of the K&B data in collaboration with Dr. Oluwatoyosi Owoeye and Dr. Sarah Richmond (post-doctoral fellow), leading to manuscript preparation. Carla van den Berg will be preparing a manuscript based on her MSc thesis, which she defended in October 2015. Carlyn Stilling (MSc student) started her program in September 2015. She is involved in this project and will develop her research project proposal within this program.

8. Presentations

Sarah Richmond PhD (2015). Examining measures of adiposity as risk factors for sport-related injury in adolescents. Canadian Academy of Sport and Exercise Medicine Annual Symposium, Ottawa, Ontario, Canada. Presentation.

Sarah Richmond, J Kang, PK Doyle-Baker, A Nettel-Aguirre, CA Emery. A school based injury prevention program to reduce sport injury risk and improve healthy outcomes in youth: a pilot, cluster-randomized controlled trial (in review: Canadian Journal of Sport Medicine).

Rebecca Carnduff (2015). Sport and recreational injury prevention knowledge uptake and beliefs in junior high school students.Canadian Academy of Sport and Exercise Medicine Annual Symposium, Ottawa, Ontario, Canada. Poster.

Rebecca Carnduff, Carla van den Berg (2015). Sport and recreation injury prevention in adolescents. Shaping the Future conference. Kananaskis, Alberta, Canada. Workshop.

Carla van den Berg, Sarah Richmond, Carolyn Emery, Patricia Doyle-Baker. (2015). Associations between body composition, lower body muscular strength, cardiorespiratory fitness, and balance in adolescents with injury compared to uninjured adolescents. Canadian Academy of Sport and Exercise Medicine Annual Symposium, Ottawa, Ontario, Canada. Poster.

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