EFFECTS OF BMI STATUS ON THE OCCURRENCE AND RECOVERY FROM INJURIES IN YOUTH

by

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A thesis submitted to the Department of Community Health and Epidemiology in conformity with the requirements for the degree of Master of Science

Queen’s University
Kingston, Ontario, Canada
August, 2009

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Abstract

Background: Injury and obesity are two of the leading public health problems in youth around the world. To reduce the burden of obesity, efforts are underway to increase physical activity participation; however, physical activity is also the leading cause of injury in youth. Recovery from injury is also important as long periods away from regular activity can have major effects on the health of youth.

Objectives: This thesis is in manuscript format. The objective of the first manuscript was to determine whether relationships between physical activity and physical activity injuries are modified by BMI status in Canadian youth. The objective of the second manuscript was to examine the effect of BMI status on the time to recovery within youth who have suffered an injury.

Methods: Data were obtained from the 2006 and 2002 Canadian Health Behaviour in School-Aged Children (HBSC) surveys. The 2006 Canadian HBSC was a nationally representative survey of 9672 youth in grades 6 through 10 from across Canada. The 2002 Canadian HBSC was an analogous survey of 7235 youth, of which approximately 50% experienced a medically treated injury. Analyses were driven by theory, and considered relationships among the major variables.

Results: In manuscript 1, cross-sectional analyses indicated that those who reported high levels of physical activity experienced greater risks for physical activity injury in comparison to those with low levels of activity. BMI status was not identified as an effect modifier in any analyses. In manuscript 2, recovery for youth who were obese and suffered a combined injury (broken bone and strain/sprain) were longer than recovery...
times for normal weight youth. Times to recovery for obese youth were not significantly elevated for broken bones and sprain/strains.

**Conclusions:** Physical activity participation relates to injury experiences in a consistent manner across BMI groups. Special safety precautions are not justified for obese youth in physical activity programs. BMI status was found to influence times for injury recovery. These are important clinical results that demonstrate that obesity may have a role in the osteoarticular health of youth and should be considered as a factor in treatment plans.
Co-Authorship

This thesis is the work of Joel Warsh in collaboration with his advisors Dr. William Pickett and Dr. Ian Janssen. For both Manuscripts: (1) *The effects of BMI on the occurrence of physical activity injuries in youth*, and (2) *The effects of BMI on injury recovery in youth*, the idea for using the HBSC to examine the effects of obesity on the relationship between physical activity and physical activity injuries was a collaborative effort between the study authors.

The body of writing, primary statistical analysis and interpretation of results were performed by Joel Warsh. All aspects of the thesis including the writing, analysis, and interpretation were edited extensively by the two thesis advisors.
Acknowledgements

I would like to extend my warmest appreciations and thanks to all individuals who guided and supported me through this process.

I would first like to thank my supervisors, Dr. Pickett and Dr. Janssen for their guidance and support through the process. Their expertise and encouragement in developing the thesis allowed me to expand my knowledge and skills throughout the experience. Their feedback was extremely timely and allowed me to complete the components of the thesis quickly and thoroughly. I am extremely lucky to have two amazing experts in their respective fields who collaborate so efficiently.

Second I would like to thank all of the epidemiological staff at Queen’s that helped me through my MSc thesis including instructors and administrative staff. Additionally, I would like to thank all of my colleagues especially within my lab in Kingston General Hospital, but also any other students who helped me with my thesis within and outside the department of Community Health and Epidemiology.

Finally, I would like to thank the Ontario Graduate Scholarship and the Canadian Institute of Health Research (CIHR) Banting and Best Master’s award and my supervisors for their financial support from the Canadian Institutes of Health Research (Grants MOP 394-792 and MOP-CHI-128223).
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<tr>
<td>BMI</td>
<td>Body mass index</td>
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<tr>
<td>CI</td>
<td>Confidence Interval</td>
<td></td>
</tr>
<tr>
<td>HBSC</td>
<td>Health Behaviour in School-Aged Children</td>
<td></td>
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<tr>
<td>HDL</td>
<td>High-density lipoprotein</td>
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<td>HR</td>
<td>Hazard Ratio</td>
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<td>LDL</td>
<td>Low-density lipoprotein</td>
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<td>OR</td>
<td>Odds Ratio</td>
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<td>RR</td>
<td>Relative Risk</td>
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<td>SES</td>
<td>Socioeconomic Status</td>
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Chapter 1 - Introduction

1.1 General Introduction

Canadian children and youth are confronted with many health issues. The 2008 Health Behaviour in School-aged Children (HBSC): Healthy Settings for Young People in Canada report indicates that the most important health issues and behaviours faced by Canadian youth are: (1) smoking and other risky behaviours (e.g., alcohol, drugs); (2) physical inactivity; (3) poor nutrition; (4) overweight and obese BMI status; (5) and medically treated injury [1]. Research into health and associated health behaviours is essential for the development of effective health and clinical interventions targeted at young people.

Injury and obesity are two of the highlighted issues in the Canadian HBSC report, and represent the main themes of this thesis. Obesity rates continue to rise [2] and the full effects of BMI on the occurrence of and recovery from injuries remain unknown. Physical activity is one area of recent interest and is used as a prevention and treatment method for obesity, but studies on injuries related to physical activity, particularly as they pertain to obese children, are lacking. The purpose of this thesis is to explore the effects of BMI on the occurrence of, and subsequent recovery from unintentional injuries in youth.
1.2 Objectives and Hypotheses

**Manuscript 1**: To examine whether relationships between physical activity and physical activity injuries are modified by BMI status in Canadian youth. It was hypothesized that BMI status would significantly modify the relationship between physical activity and physical activity injuries. Obese and overweight youth were expected to be at a greater risk for injury for a given level of physical activity. The analyses were conducted for injuries sustained both inside and outside of school environments, and it was expected that the relationship would be stronger outside of schools.

**Manuscript 2**: To examine the effect of BMI status on the time to recovery within Canadian youth who have suffered a musculoskeletal injury (broken bones, strains/sprains). It was hypothesized that obese and overweight youth who suffered an injury would take significantly longer to recover than those with a healthy weight.

1.3 Anticipated Results and Significance

It was hoped that the findings of this study would provide an understanding of the effects of: (1) BMI on the occurrence of physical activity injuries in Canadian youth; (2) BMI on recovery from injury among injured young Canadians. Results would then have the potential to inform policy and programming. If obese youth were found to be at an increased risk for injury, special safety precautions would be warranted for obese youth in physical activity programs. If no differences were found, the analyses would provide re-assurance that physical activity participation relates to injury experiences in a consistent manner across BMI groups and that no special precautions are necessary.
Results from manuscript 2 have the potential to inform prognoses for injury recovery made by clinicians. Special considerations in the tertiary management of common types of injury may be needed for overweight and obese individuals. Longer recovery times for obese youth would lead physicians to provide recommendations for a longer rest period to prevent re-injury.

1.4 Thesis Organization

This thesis conforms to the regulations outlined in the Queen’s University School of Graduate Studies and Research. The second chapter summarizes previous studies that are of relevance to the thesis topic. The third chapter (Manuscript 1) is an analytical study, exploring the effects of BMI on the relationship between physical activity and physical activity injuries in Canadian youth. This manuscript has been submitted to the *International Journal of Pediatric Obesity* and is formatted accordingly. The fourth chapter (Manuscript 2) is an analytical study exploring the effects of BMI on the recovery from injuries in Canadian youth. This manuscript has been submitted to *Injury Prevention* and is formatted accordingly. Chapter 5 contains a general discussion of the findings, study conclusions, and contains a brief summary.
1.5 Funding

Dr. Janssen and Dr. Pickett received funding from the Canadian Institutes of Health Research (CIHR) to examine the relationship between injury and obesity in Canadian populations. The financial support comes from the Canadian Institutes of Health Research (Grants MOP 394-792 and MOP-CHI-128223). This thesis represents one component of the larger project. Joel Warsh was funded by a CIHR Banting and Best Master’s Award and a student fellowship from the Ontario Graduate Scholarship program.

References


Chapter 2 - Literature Review

2.1 General Introduction

Unintentional injury and obesity are arguably the most important public health issues for Canadian children and youth [1-4]. Injury is the leading cause of death and a major cause of morbidity amongst youth aged 14 years and under in Canada [5]. Obesity is also a major problem in youth [2]. In 2004, 26% of Canadians aged 2 to 17 were overweight or obese, compared to 12% in 1979 [6].

Physical activity is generally regarded as a fundamental component of obesity prevention and treatment [7]. Although physical activity is regarded as being a positive factor in weight management, it is also important to note that physical activity is the leading cause of unintentional injury among youth [8].

Once a child is injured, a primary goal is to return to school or normal activity in an expedient manner. Poor weight management has been linked to numerous health consequences [2] and recently, longer injury recovery has been postulated to be a consequence of obesity [9]. Results from several studies suggest that BMI may play a role in these times of recovery from injury [9-11].

Figure 1 describes the conceptual framework underlying this thesis. In manuscript 1, the research explores potential modifying effects of BMI status on the relationship between physical activity and physical activity injuries. In manuscript 2, the research explores the effects of BMI on times to recovery from injury.
Figure 1: Conceptual pathway describing: 1) where BMI is hypothesized to modify the relationship between physical activity and physical activity injury, and 2) where BMI is hypothesized to directly effect times for injury recovery.

There is an extensive body of literature describing the health importance of each of the major variables (physical activity, BMI, injury, recovery) as well as their inter-relationships. Background literature was identified through electronic databases and website search. Relevant references from selected articles were also retrieved through
“snowballing” techniques. This is helpful to identify cited references from important papers.

2.2 Key Definitions

*Injury* is defined as any physical harm to the body caused by an external force that results in medical treatment [3]. *Unintentional injuries* include falls, motor vehicle crashes, pedestrian injuries, drowning, suffocation, poisoning and fires, but do not include suicide or acts of violence [3]. *Injury Recovery* is operationally defined here as the amount of time that an injury caused an individual to miss school or other usual activities, such as sports or lessons [12]. *Overweight and obesity* are conditions in which an individual has excess body fat, to the extent that it may influence their health in a negative way [13]. *Physical activity* is defined as any bodily movement produced by the skeletal muscles that results in a significant increase in energy expenditure [14]. Physical activity therefore includes non-vigorous (e.g., light walking) and vigorous tasks (e.g., brisk walking, jogging, playing sports). In general, physical activities of moderate-to-vigorous intensity are those that will make the individual breathe more deeply and rapidly and increase their body temperature [15]. *Youth* is defined as the time between childhood and maturity [16], and in this thesis refers to the 11-15 year age period.
2.3 Public Health Relevance of Injury and Obesity

2.3.1. Unintentional Injury

Each year, approximately 50% of Canadian boys and 40% of girls are likely to experience at least one injury requiring medical treatment [15]. Additionally, on an annual basis 20% of boys and 10% of girls report one or more serious injury requiring placement of a cast, stitches, surgery, or overnight admission to hospital [15]. Since the 1940’s, unintentional injuries have caused more deaths in Canadian children aged 1 to 19 years than all infectious diseases combined [15]. Injuries are also the leading cause of disability in the pediatric population [17]. The estimated economic burden of injuries is substantial [18].

Within selected Canadian hospitals, emergency department visits are studied and monitored using the Canadian Injury Reporting and Prevention Program (CHIRPP). The most common types of pediatric injuries are fractures, open wounds, and superficial injuries (20% for each category). Injuries account for approximately 25% of all emergency department visits, of which 13% present with broken bones and 20% present with strains and sprains per year and 2% other injuries [19]. Injuries to the head and neck (35%) and to the arm (34%) account for two-thirds of the anatomical sites of injuries identified [20]. In terms of external cause, major causes of serious injury include road traffic accidents, poisoning, falls, and drowning [21]. More than half (57%) of Canadian children are injured while they are involved in physical activity, and 8% of these injuries took place on roads [20].

The past 25 years have led to substantial progress in defining the epidemiology of
childhood injury. Despite impressive reductions in unintentional childhood injury deaths, injury remains the most important cause of death and disability for children and adolescents. There are many types and mechanisms of injury, and one of the most important contributors to injury is physical activity.

2.3.2 Overweight and Obesity

The prevalence of overweight and obesity in youth has risen in Canada and around the world [2]. In 1978/79, 12% of 2-17 year old Canadians were overweight and 3% were obese [22]. By 2004, the overweight rate for this age group was 18% (an estimated 1.1 million) and 8% were obese (about half a million) [23]. An American study looking specifically at youth found that obesity-associated annual hospital costs increased to more than $127 million (1.70% of total hospital costs) [24].

Overweight and obesity are known to have numerous adverse health consequences. A pattern of elevated low-density lipoprotein (LDL) cholesterol and lowered high-density lipoprotein (HDL) cholesterol is often observed in obese youth, and these are risk factors for cardiovascular disease later in life [25]. Additionally, glucose intolerance, sleep apnea, and diabetes are co-morbid conditions of obesity in youth [26].

Obese youth also tend to have psychosocial issues including lower self esteem (9), they become the targets of discrimination [27] and have a negative self image (3). There can be long-term social consequences to overweight youth including lower college/university acceptance rates (11) and less years of marriage in their later years (14).

Physical activity is a recommended method of weight control in pediatric obesity treatment programs [28, 29], and has demonstrated benefits in addition to weight
maintenance/loss in youth including improved psychosocial health [30], bone growth [31], blood pressure, asthma symptoms, and muscular strength and endurance [32].

2.4 Relationship Between Obesity and Injury

Overweight youth are at increased risk for many medical problems including trauma and injury. The few studies specifically examining the relation between obesity and injury in youth report an increased odds of overall injuries [33, 34], wrist fractures [35], ankle injuries [36], and musculoskeletal pain of the joints [37]. Table 2 summarizes this research that looks at obesity and injuries in youth.
Table 1: Findings from obesity and injury studies in children and youth

<table>
<thead>
<tr>
<th>Study</th>
<th>Age (y)</th>
<th>Gender</th>
<th>Number</th>
<th>Design</th>
<th>Obesity Measure</th>
<th>Injury Measure</th>
<th>Effect Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goulding et al. [38]</td>
<td>3-15</td>
<td>F</td>
<td>200</td>
<td>Cohort study</td>
<td>BMI</td>
<td>Fracture presenting in hospital</td>
<td>HR 1.49; 95% CI, 1.06-2.08</td>
</tr>
<tr>
<td>Chau et al. [39]</td>
<td>Middle and High school</td>
<td>F and M</td>
<td>2398</td>
<td>Cohort study</td>
<td>BMI</td>
<td>School survey questionnaire</td>
<td>OR 3.24; 95% CI 1.08-9.78</td>
</tr>
<tr>
<td>Bazelmans et al. [40]</td>
<td>9-17</td>
<td>F and M</td>
<td>2363</td>
<td>Cross sectional survey and physical exam</td>
<td>BMI</td>
<td>Survey question on serious injuries</td>
<td>OR 1.42; 95% CI 1.13-1.79</td>
</tr>
<tr>
<td>Zonfrillo et al. [36]</td>
<td>5-19</td>
<td>F and M</td>
<td>360</td>
<td>Case-control</td>
<td>BMI</td>
<td>Presented at ED with ankle injury</td>
<td>RR, 1.70; 95% CI 1.10-2.61</td>
</tr>
</tbody>
</table>

HR- Hazard Ratio; OR- Odds Ratio; CI- confidence interval; RR – relative risk; M- Male; F- Female; BMI- Body Mass Index; ED – emergency department.
Existing studies found that efforts to promote optimal body weight may reduce not only the risk of chronic diseases in the long-term [40], but also the risks for unintentional injury among overweight and obese individuals in the short-term [36]. There was a consistent trend across studies in that higher risks for injury were observed in association with an overweight or obese BMI status. High body weight increased the risk for fractures, ankle injuries, and total injuries [36, 40, 41].

There is a lack of research that has examined the modifying effect of BMI on the relationship between physical activity and injury. Regular physical activity helps children to maintain a healthy weight and a normal BMI status [42]. It helps to reduce general anxiety, and has positive effects on academic performance and skill development [42]. While physical activity is generally recognized as having a positive influence on the health and well-being of young people, it is also known to be the leading cause of unintentional injury in Canadian youth [8]. In fact, prior research suggests that more than half of the injuries requiring medical attention occur during sports or recreational activities [3, 43].

There are documented methodological limitations to the research in this field. These include: (1) the cross-sectional nature of the data which limits ability to sort out cause and effect [33, 39, 40]; (2) studies have examined BMI and injury but not as the main variables. They looked at these as secondary objectives [39, 41]; (3) studies have not all examined specific external causes of injury (e.g., activity, traffic injury) [40]; (4) they have also not taken into account the important role of physical activity which may be a major factor in the obesity-injury relationship [44].
2.5 Biological Basis for Relationships Between Obesity and Injury

Several key biological and biomechanical mechanisms may account for observed relationships between obesity and injuries. Figure 2 describes the biomechanical factors that are likely to play a role in these relationships.

![Figure 2: Biomechanical factors that affect the relationships between obesity and injuries](image)

Functional and structural limitations imposed by obesity may result in improper lower limb mechanics and the potential for musculoskeletal injury [45]. During childhood, the physis (end of bones) tend to compensate for these loads, but are also weaker than the center of the bones and may become deformed [46]. This is why obese youth, during the phases of major anatomical varus (angled inward) (18–20 months) or valgus (angled outward) (3 years) of the knees, tend to display greater numbers of deformities [46].
Obese youth tend to have poorer health practices including poor nutrition and physical activity participation, and therefore may be more likely to suffer an injury [47]. Poor nutrition and bone development, combined with increased forces during injury in overweight and obese youth can lead to more severe injuries [45]. Injuries caused by strong forces in the downward direction could be more damaging to obese youth with the increased forces on their bones [45]. Increased BMI could lead to higher forces through the equation force = mass x acceleration. Should the injury event occur in the same direction as the body acceleration, the increased mass would cause a greater force and thus a more severe injury. Many injuries can be exacerbated by increased weight. Acceleration injuries might include the leg slipping forwards when the body is stationary and unprepared. When the body hits the ground the added weight increases the forces in the direction towards the ground and can lead to a greater injury.

Certain injuries may not be affected by increased weight including deceleration injuries like catching a ski in a mogul. The body weight is in the downward direction but the acceleration is in the forward direction and therefore the injury may not be exacerbated by body weight. Torque mechanisms such as kicking and twisting the body while the other foot is 'planted' on the ground are also enhanced by increased weight. The higher the force (mass x acceleration), the greater the torque and therefore more obese individuals would have increased torque on their muscles and bones which could lead to more severe injuries.
Overall, obesity has a negative impact on the osteoarticular health of youth by promoting biomechanical and biological changes in the musculoskeletal system that may lead to an increased risk for injury.

2.6 Inter-Relationships Between Injury, Physical Activity, and Obesity

Evidence surrounding the effects of obesity on the relationship between physical activity and the occurrence of physical activity injuries is limited. Obesity has been linked to injury caused by physical activity in the form of fractures and sprains [8, 48]. From a public health perspective, it is important to identify strategies for increasing physical activity without increasing risk for injury. If this is accomplished, youth would receive the health benefits associated with increased fitness without the increased burden to the health care system from injuries. Etiological research is fundamental to the development of such strategies.

One approach is to identify vulnerable groups who are particularly susceptible to physical activity injuries. If these groups can be identified, targeted interventions can be used to reduce the risk for injury. Overweight and obese youth may represent such a vulnerable group. With the growing trend of obesity, it is vital to identify strategies for increasing physical activity that do not put vulnerable populations at higher risk for injury, and thus dissuade youth from participation.

2.7 Recovery from Injury and Obesity

Once a child is injured, a primary goal is to recover quickly and return to normal activity. Factors that influence recovery from injury in youth have not been examined extensively, especially with respect to BMI. Identification of vulnerable groups may
isolate those who need special treatment or care, and obese youth may be one of these groups.

A study that has examined BMI as a risk factor for impaired recovery following injury in youth found an increased risk for complications and a greater recovery time following severe medical trauma [49]. Lean and obese groups were similar by age, sex, mechanism of injury, admission vitals, injury severity, and the operations required. Additionally, injury patterns were similar, except that obese patients had less severe head injuries. Although there was no difference in mortality among obese and non-obese patients ($P = .39$), obese youth had more complications (41% vs 22%, $P = .04$). In addition, obese patients required longer stays (mean (SD) of 8 ± 9 vs 6 ± 6 days, $P = .05$) after severe trauma [49]. A major limitation of this study was that other co-morbid health conditions were not taken into account. As many as 20-30% of severely obese youth have cardiovascular disease and elevated blood pressure that may play a role in adverse consequences of injury [49].

Another study reported that obesity increased the risk for complications from femoral fractures. In this study, 59 fractures were treated with external fixation, and 45 were treated with an intramedullary rod. When examined according to treatment groups, the complication rate for more obese youth was higher within the group managed with an intramedullary rod and the group that had external fixation ($P = .004$) [11]. The main limitation of this study is that standard calculation of BMI was not possible as height values were not available for most children [11]. Instead, standard age-weight tables were used. This could have led to misclassification of study participants.
Overweight and obese youth are more likely (relative risk, 1.70; 95% confidence interval, 1.10-2.61) to have persistent pain, swelling and re-injury following an ankle sprain [9]. There were issues of convenience sampling in the cited study as the study sample was drawn from one hospital. This limits the generalizability of the findings [9].

2.8 Summary of Literature

There is increasing interest in the relationship between obesity and injuries. Both are major public health issues in youth, and therefore their effects on each other are important to study. Research has consistently found increasing risks for injury in overweight and obese youth. Recovery from injury takes longer and there are more complications in overweight and obese youth. Gaps in the literature include the cross-sectional nature of study designs, convenience sampling, and poor measures of the main variables. These limitations should be addressed to fully explore and understand this important relationship.

2.9 Thesis Rationale

The proposed thesis is important for several reasons: 1) unintentional injury and obesity are major public health issues; 2) there is a need for new etiological understanding of potential causes of injury; 3) short term health outcomes associated with obesity are poorly described; and 4) the relationship between obesity and injury recovery has not been extensively and appropriately explored. The study will provide novel data that will be useful for prevention of injuries and obesity.

To my knowledge, this will be one of the first studies in Canada to look at the effects of BMI on the inter-relationships between physical activity, unintentional injury,
and injury recovery in youth. Given the high prevalence of obesity and injury in Canada, even small increases or decreases in the risk for injury in the overweight population could have large impacts at the population level.

References


Chapter 3 - Manuscript 1

Are overweight and obese youth at increased risk for physical activity injuries?

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Type of manuscript: Original article
Running Head: BMI and physical activity injury
Total word count (Abstract): 304
Total word count (text only): 2366
Number of pages: 19
Number of tables: 4
Number of figures: 1
Number of references: 38

Key Words: Obesity, Injury, Physical Activity, Youth, Population Health.
Abstract

**Background:** The prevalence of obesity in youth continues to rise. To reduce this burden, efforts are underway to increase physical activity participation. All youth have been encouraged to be physically active, irrespective of their BMI status. While generally seen as positive, physical activity does have negative side effects in terms of excess risks for injury.

**Objective:** To determine whether relationships between physical activity and associated physical activity injuries are modified by BMI status in Canadian youth.

**Methods:** Data were obtained from the 2006 Canadian Health Behaviour in School-Aged Children (HBSC) survey; a nationally representative study of 9672 youth in grades 6 through 10 from 188 public schools across Canada. A sub-sample of 2,039 students from 16 high schools in Ontario was re-administered the survey in 2007. Analyses considered potential relationships among the major variables in theory-driven cross-sectional and longitudinal etiological analyses.

**Results:** Among normal weight children, cross-sectional analyses indicated that those who reported high levels of physical activity experienced 1.38 (95% CI 1.05-1.82) times the risk for physical activity injury in comparison to those with low levels of activity. Analogous rate ratios for overweight/obese children were 1.07 (95% CI 0.34-1.17). In settings outside of school, relative risks for physical activity injury were 1.83 (95% CI 1.67-2.01) and 1.83 (95% CI 1.46-2.24) for the normal and overweight/obese groups, respectively. BMI status was not identified as an effect modifier in any analyses. In confirmatory longitudinal analyses, there were no significant interaction effects found between physical activity, physical activity injury, and BMI status.
Conclusions: Concerns surrounding the design of physical activity programs include potential side effects such as increased risks for injury. The present analysis provides some re-assurance that physical activity participation relates to injury experiences in a consistent manner across BMI groups. By extension, physical activity programs should consider being inclusive of all youth irrespective of BMI status.
Introduction

Obesity is a leading public health problem among young people. The prevalence of overweight and obese youth has risen in Canada compared to historical norms [1]. In 2004, 26% of Canadians aged 2 to 17 were overweight or obese compared to 12% in 1979 [2].

To reduce the prevalence of overweight and obese youth, efforts are underway to increase physical activity participation [3]. Recently published evidence-based physical activity guidelines for school-aged children and youth suggest a minimum of 60 minutes of moderate-to-vigorous intensity physical activity on a daily basis, with a focus on aerobic activities [4]. The evidence that informed these recommendations focused on the positive aspects of physical activity. However, physical activity is also a leading determinant of medically treated injuries in youth [5]. Studies that examine the negative effects of physical activity are warranted in order to inform physical activity recommendations that are optimal for both health and safety.

BMI status may play a modifying role in the relationship between physical activity and physical activity injuries (Figure 1). Because overweight and obese children are vulnerable populations who are encouraged to engage in high levels of physical activity to manage their excess BMI, it is vital to identify whether physical activity participation places them at increased risk for injury. We had the opportunity to study this issue in a population-based series of analyses. The objective was to examine the potential modifying effects of BMI on the relationship between physical activity and physical activity injuries. This was done using a large, nationally representative sample
Methods

Design and Sample

The study involved a cross-sectional analysis of health data collected from Canadian children, with longitudinal confirmation of key relationships. The principle data source was the 2006 Canadian Health Behaviour in School-Aged Children (HBSC) survey [3]. This survey was conducted in collaboration with the World Health Organization and follows an international scientific protocol [6]. The HBSC employed a cluster design, with randomly selected classrooms reflecting provincial distributions of schools by size, location, language, and religion [6]. Excluded were youth attending special schools (private, special-need, home), incarcerated youth, or street youth. Combined, these youth represented less than 10% of the defined population in Canada [7]. Self-reported information on demographic and psychosocial factors, health behaviours, and health outcomes was collected from participants. Approximately 75% of students that were approached participated [6].

National Cross-Sectional Sample

The 2006 cross-sectional sample involved 9672 youth in grades 6 through 10 from 188 public schools. Students were excluded from the present analysis due to incomplete information on BMI (n=1735), physical activity (n=128) and injuries (n=68). Records from 7741 (80%) of the students were analyzed. Those who were not included
tended to be younger and female (data not shown). General procedures for the administration of the HBSC are listed in appendix A.

**Ontario Longitudinal Sample**

In addition to the national sample, 2039 grade 9 and 10 students from 16 Ontario high schools were administered the HBSC on two occasions, in the spring of 2006 and then 2007. Of these, 1814 (89%) provided complete data for the BMI and physical activity variables at baseline (2006) and the injury items at follow-up (2007) and were available for the confirmatory longitudinal analyses.

**Variables for Study**

**Exposure (Physical Activity)**

Three HBSC items measured moderate-to-vigorous intensity physical activity: (1) the number of hours of physical activity performed in school during class time, (2) the number of hours of physical activity performed in school during free time, (3) the number of hours of physical activity performed outside of school. For the within school physical activity questions, there were 9 possible response categories that ranged from “none” to “7 hours or more per week” [8]. The two measures (in class and in free time) were summed to create an overall measure of in-school physical activity. For physical activity outside of school, there were 7 possible response categories that ranged from “none” to “7 hours or more per week” [8]. Physical activity scores were grouped into low (<3 hours/week), moderate (3-6 hours/week), and high (>=7 hours/week) categories for both the within school and outside of school measures [8]. These categories corresponded with daily activity levels of <30 minutes, 30-60 minutes, and ≥ 60 minutes [8]. Cut-points were chosen based on prior research [9, 10]. The self-reported physical activity
measures used here provide reasonably valid estimates when compared with objective measures from accelerometer data, with kappa values of 0.6 [11, 12].

**Outcome (Physical Activity Injuries)**

An initial question that stated “During the past 12 months, how many times were you injured and had to be treated by a doctor or nurse?” was used to identify reported injury events. Medically treated injury occurrences that result in a loss of normal activity has been recommended as a valid [13] and reliable proxy for defining injury in survey data with kappa scores of 0.89-0.92 [14]. A series of follow-up questions requested information on the activity leading to the injury and the physical location where the injury occurred. Physical activity injuries were defined as those occurring due to “biking/cycling”, “playing or training for sports/recreational activity”, “skating” or “walking/running”. Each physical activity injury reported was also classified as occurring either on or off school grounds [8].

**Potential Effect Modifier (BMI)**

The body mass index (BMI), calculated as self-reported values for weight in kg divided by height in m² (kg/m²), is the most commonly used index of BMI status among youth [15]. The International Obesity Task Force age-and gender-specific BMI standards for youth were used to classify participants as being normal weight, overweight, or obese [16]. Growth curves have been created for use in calculating BMI status in youth where at age 18, the curves pass through the adult cut-points of 25 (overweight) and 30 (obese) kg/m². For the purposes of this analysis, overweight and obese youth were combined into a single group.
Self-reported BMI is a reliable method of measurement despite slight underestimation, particularly among females [17, 18]. High correlations between self-reported and measured height, weight and BMI have been reported. Measured and self-reported values also relate to health outcomes in a similar manner [17, 18].

**Confounders**

Variables considered *a priori* as potential confounders were gender, grade, socioeconomic status, and perceived health. Females are less physically active than males, and male youth become injured more than girls [19]. Furthermore, older youth are less physically active and more prone to injury [19]. Socioeconomic status was measured via the Family Affluence Scale (FAS). Responses to questions regarding vehicle and computer ownership, bedroom sharing, and holiday travel contribute to this scale [20]. The FAS is reliable in that student reports are in agreement with parental reports. It is also sensitive in distinguishing between varying levels of affluence measured using alternative methods [20]. Perceived health was considered to be important as youth are known to be less physically active if they are not healthy [21, 22] and individuals with health complications are more likely to become injured [23, 24]. Self-reported measures of health have been proven to be reliable indicators of general health status in large population health surveys [25].

**Analysis**

Descriptive analyses were used to profile characteristics of the 2006 national cross-sectional sample. Next, a series of logistic regression analyses were conducted. Model development was based upon *a priori* identification of potential confounders from existing literature. A backwards stepwise selection procedure confirmed a parsimonious
set of confounders for potential analyses in multiple logistic regression models [19]. A product term of physical activity x BMI status (normal weight, overweight, obese) was inserted to evaluate the potential for effect modification. Models developed cross-sectionally were confirmed using the Ontario longitudinal data.

All statistical analyses were performed using SAS version 9.1 (SAS Institute, Cary NC). The SAS GENMOD was used to fit a model for physical activity injury with a binomial distribution and logit link. The exchangeable working correlation matrix specified by the CORRW option was used. This is the standard correlation matrix for the GENMOD procedure. Multi-level modeling techniques were used to control for the effects of clustering in the data set as students were recruited in classes [26]. Because injury is a common outcome, the odds ratio effect measures were converted to rate ratios with their corresponding 95% confidence intervals [27]. Rate ratios (RR) were derived by adjusting odds ratios (OR) by the proportion of the outcome in the referent groups (P₀) as follows: RR=OR/((1-P₀) + (P₀ x OR)) [27].

Results

Cross-Sectional Analysis

The national cross-sectional sample is described in Table 1. Larger percentages of youth experienced physical activity injuries outside of school (23.2%) as compared to in school (5.9%). There was a higher percentage of normal weight youth with moderate levels of physical activity as compared to overweight and obese youth. Obese youth had larger percentages than normal weight youth at the extremes (low and high levels of
physical activity). Injuries were most often treated in physicians’ offices (50.1%); 17.4% were more serious as indicated by treatment via cast, stitches, surgery or an overnight hospital stay. The majority of participants reported being in the low physical activity group. Most of the schools were public (82.4%) and situated in urban areas (61.8%).

Bivariate associations between physical activity injury and each of the potential confounders are presented in Table 2. In school environments, youth had a higher risk for physical activity injury if they were male, in grades 6-8, had a lower socioeconomic status, and reported ‘fair’ perceived health. Outside of school, youth reported a higher risk for injury if they were male, in grades 9-10, had a high socioeconomic status, and had ‘excellent’ perceived health.

Table 3 summarizes bivariate and multivariate relationships between physical activity and physical activity injuries experienced in and out of schools, stratified by BMI status. In normal weight youth, those who performed high levels of physical activity at school had 1.38 (95% CI, 1.05-1.82) times the risk for physical activity injury in comparison with those who reported low levels. Normal weight youth who performed high levels of physical activity outside of school experienced 1.83 (95% CI, 1.67-2.01) times the risk for physical activity injury outside of school in comparison to normal weight youth with low physical activity participation. Overweight and obese youth in the high physical activity category also had 1.83 (95% CI, 1.46-2.24) times the risk for injury. There were no significant interaction effects found between physical activity and BMI on physical activity injuries for the within school and outside of school injury outcomes.

Longitudinal Analysis
Table 4 presents the results of the confirmatory longitudinal regression analyses conducted in the subsample of grade 9 and 10 Ontario youth. Relationships were similar to those found in the cross-sectional analyses. In all cases, youth with high levels of physical activity were at greater risk for physical activity injuries in comparison to youth who were not physically active. BMI status did not modify the relationship between physical activity and physical activity injuries, in settings both within schools and outside of schools.

**Discussion**

Findings from this study demonstrate that youth who engage in high levels of physical activity outside of school experience higher risks for physical activity injuries, irrespective of their BMI status. In contrast to the theoretical framework (Figure 1), neither the cross-sectional or longitudinal analyses suggested that BMI status modifies the relationship between physical activity and physical activity injuries. It should be noted that only a small proportion of the sample was obese and therefore true effects may not have been seen in due to power limitations. Normal weight youth and overweight/obese youth had a slightly different pattern of physical activity. Normal weight youth tended to be moderately physically active. Overweight or obese youth had higher percentages than normal weight youth for the low and high categories of physical activity. This suggests that some overweight/obese individuals are not active which is a likely factor in their weight status whereas others are highly active in athletics or methods of weight control. Since youth with the highest levels of physical activity are more likely to be injured, differing levels of activity between the groups could have been a factor in the overall results.
The potential for BMI status to modify relationships between physical activity and physical activity injury has not been explored extensively in prior analyses. However, significant differences in overall injury risk [28, 29], wrist fractures [30], ankle injuries [31], and musculoskeletal pain of the joints [32] have been identified across BMI groups. Our failure to find evidence of the modifying effects of BMI status may be attributable to the fact that specific types and anatomical sites of injury were not available for examination. For example, it is possible that these effects could be observed for fractures and soft tissue injuries to the lower limbs, each of which could be biomechanically related to the forces associated with larger body weights. Our analyses were only able to study combined groups of fractures and other injuries, due to the lack of information on anatomical site. This would have biased any observed effects towards the null, and masked the existence of such findings.

The minimal differences in the size of effect estimates between physical activity and injury observed between BMI groups provides encouraging news for program planners and physical activity educators. Physical activity is a recommended method of weight and BMI control in pediatric obesity treatment programs [33, 34], and has demonstrated benefits in addition to weight maintenance/loss in youth including improved psychosocial health [35], bone growth [36], blood pressure, asthma symptoms, and muscular strength and endurance [9]. Being overweight did not appear to exacerbate the risks for physical activity injury in our study. By extension and taken in context of the literature, our findings suggest that physical activity should continue to be used as an integral part of weight reduction programs within overweight and obese youth as it did
not carry an added risk for injury, a key negative health outcome of physical activity. More research should be conducted on this topic to confirm the relationships found.

Strengths of this study include the fact that it was based on a large sample of Canadian youth, the validated survey procedures, the multilevel modeling used for analysis, and the confirmation of the cross-sectional findings in the longitudinal component of the analyses. Limitations of this study also warrant comment. These include bias introduced by the use of self-reported information. Physical activity levels are likely to be overestimated by participating students and questionnaire measures of physical activity are poorly related to objective measures [6]. This misclassification would likely be independent of the characteristics of physical activity injury and have biased effect estimates towards the null. Furthermore, it is possible that the effects of an elevated BMI on injury risk may only be observed at extreme BMI levels (e.g., obesity per se), and since we merged the overweight and obese youth into one category, the ability to detect these differences may have been limited.

Youth are less physically active when compared with previous generations [37]. It is important to increase the amount of physical activity so that youth can remain fit and active, but this must ideally be done without substantively increasing the burden of injury in youth. As physical activity participation is a leading cause of injury, the promotion of increased physical activity could lead to increases in injury unless strategies are implemented, especially outside of supervised settings. In general, those strategies should not segregate youth based on BMI status but should be inclusive to foster safe participation by all youth.
Acknowledgements

This study was supported financially by the Canadian Institutes of Health Research (Grants MOP 394-792 and MOP-CHI-128223) and the Public Health Agency of Canada (Contract: HT089-05205/001/SS) which funds the Canadian version of the Health Behaviour in School-Aged Children Survey; a World Health Organization / European Region collaborative study. International Coordinator of the 2005/2006 study: Candace Currie, University of Edinburgh; Data Bank Manager: Oddrun Samdal, University of Bergen and all individuals who collected national and provincial data. This publication reports data solely from Canada (Principal Investigator: William Boyce and Ontario Principal Investigator William Pickett). Ian Janssen was funded by a New Investigator Award from Canadian Institutes of Health Research and an Early Researcher Award from the Ontario Ministry of Research and Innovation. Joel Warsh was funded by the Ontario Graduate Scholarship and a Banting and Best Master’s award, Canadian Institutes of Health Research.
Table 1. Descriptive analysis of the student sample (n=7741)

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>3730</td>
<td>48.2</td>
</tr>
<tr>
<td>Female</td>
<td>4011</td>
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</tr>
<tr>
<td>Grade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 to 8</td>
<td>4001</td>
<td>51.7</td>
</tr>
<tr>
<td>9 to 10</td>
<td>3740</td>
<td>48.3</td>
</tr>
<tr>
<td>Physical Activity Injuries</td>
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<td></td>
</tr>
<tr>
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<tr>
<td>Out of school</td>
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<td>23.2</td>
</tr>
<tr>
<td>Physical Activity In School</td>
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<td></td>
</tr>
<tr>
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</tr>
<tr>
<td>Medium</td>
<td>2665</td>
<td>34.4</td>
</tr>
<tr>
<td>High</td>
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<td>28.5</td>
</tr>
<tr>
<td>Physical Activity Out Of School</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
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<td>60.7</td>
</tr>
<tr>
<td>Medium</td>
<td>1666</td>
<td>21.5</td>
</tr>
<tr>
<td>High</td>
<td>1376</td>
<td>17.8</td>
</tr>
<tr>
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<tr>
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<tr>
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</tr>
<tr>
<td>Obese</td>
<td>419</td>
<td>5.4</td>
</tr>
<tr>
<td>Normal Weight (n=6111)</td>
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<td></td>
</tr>
<tr>
<td>Low</td>
<td>1956</td>
<td>32.0</td>
</tr>
<tr>
<td>Medium</td>
<td>2811</td>
<td>46.0</td>
</tr>
<tr>
<td>High</td>
<td>1344</td>
<td>22.0</td>
</tr>
<tr>
<td>Overweight/Obese (n=1630)</td>
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<td></td>
</tr>
<tr>
<td>Low</td>
<td>636</td>
<td>39.1</td>
</tr>
<tr>
<td>Medium</td>
<td>554</td>
<td>34.0</td>
</tr>
<tr>
<td>High</td>
<td>440</td>
<td>26.9</td>
</tr>
<tr>
<td>Treatment Location (n=2250)</td>
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<td></td>
</tr>
<tr>
<td>Doctor's office/health clinic</td>
<td>1723</td>
<td>76.6</td>
</tr>
<tr>
<td>Emergency room</td>
<td>1228</td>
<td>54.6</td>
</tr>
<tr>
<td>Hospital admission overnight</td>
<td>356</td>
<td>15.8</td>
</tr>
<tr>
<td>School health service</td>
<td>233</td>
<td>10.0</td>
</tr>
</tbody>
</table>

Physical activity scores: low (<3 hours/week), moderate (3-6 hours/week), high (>7 hours/week)
Table 2. Bivariate associations between major confounders and physical activity injury

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>% Injured</th>
<th>RR (95%CI)</th>
<th>% Injured</th>
<th>RR (95%CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physical Activity Injury In School</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 to 8</td>
<td>4001</td>
<td>6.0</td>
<td>1.00</td>
<td>22.3</td>
<td>1.00</td>
</tr>
<tr>
<td>9 to 10</td>
<td>3740</td>
<td>5.8</td>
<td>0.96 (0.81-1.14)</td>
<td>24.1</td>
<td>1.05 (0.94-1.16)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>3730</td>
<td>6.0</td>
<td>1.00</td>
<td>27.5</td>
<td>1.00</td>
</tr>
<tr>
<td>Female</td>
<td>4011</td>
<td>5.8</td>
<td>0.96 (0.81-1.14)</td>
<td>19.1</td>
<td>0.69 (0.65-0.75)</td>
</tr>
<tr>
<td>Family Affluence Scale</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>631</td>
<td>6.8</td>
<td>1.00</td>
<td>15.2</td>
<td>1.00</td>
</tr>
<tr>
<td>Moderate</td>
<td>2912</td>
<td>6.0</td>
<td>0.99 (0.73-1.34)</td>
<td>21.3</td>
<td>1.40 (1.16-1.68)</td>
</tr>
<tr>
<td>High</td>
<td>3981</td>
<td>5.9</td>
<td>0.97 (0.73-1.30)</td>
<td>25.8</td>
<td>1.69 (1.42-2.00)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>P trend = 0.36</td>
<td></td>
<td>P trend = &lt;0.0001</td>
</tr>
<tr>
<td>Perceived Health</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excellent</td>
<td>2347</td>
<td>5.2</td>
<td>1.00</td>
<td>28.3</td>
<td>1.00</td>
</tr>
<tr>
<td>Good</td>
<td>4221</td>
<td>6.2</td>
<td>1.19 (0.97-1.46)</td>
<td>22.5</td>
<td>0.79 (0.71-0.86)</td>
</tr>
<tr>
<td>Fair</td>
<td>1028</td>
<td>6.8</td>
<td>1.31 (1.03-1.66)</td>
<td>15.5</td>
<td>0.54 (0.45-0.64)</td>
</tr>
<tr>
<td>Poor</td>
<td>131</td>
<td>2.3</td>
<td>0.44 (0.15-1.32)</td>
<td>10.7</td>
<td>0.39 (0.22-0.64)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>P trend = 0.17</td>
<td></td>
<td>P trend = &lt;0.0001</td>
</tr>
</tbody>
</table>

P trend = 0.36  P trend = <0.0001
**Table 3.** Results of logistic regression analysis: Associations between physical activity and physical activity injury according to BMI status

<table>
<thead>
<tr>
<th>Physical Activity Level in School (hrs per week)</th>
<th>Bivariate</th>
<th>Multivariate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal Weight</td>
<td>Overweight/Obese</td>
</tr>
<tr>
<td></td>
<td>% Injured</td>
<td>RR (95%CI)</td>
</tr>
<tr>
<td>Low (&lt;3)</td>
<td>5.0</td>
<td>1.00</td>
</tr>
<tr>
<td>Moderate (3-6)</td>
<td>6.2</td>
<td>1.24 (0.97-1.59)</td>
</tr>
<tr>
<td>High (≥7)</td>
<td>6.6</td>
<td>1.34 (1.01-1.77)</td>
</tr>
<tr>
<td></td>
<td>P trend = 0.04</td>
<td>P trend = 0.31</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Physical Activity Level Outside of School (hrs per week)</th>
<th>Bivariate</th>
<th>Multivariate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal Weight</td>
<td>Overweight/Obese</td>
</tr>
<tr>
<td></td>
<td>% Injured</td>
<td>RR (95%CI)</td>
</tr>
<tr>
<td>Low (&lt;3)</td>
<td>17.4</td>
<td>1.00</td>
</tr>
<tr>
<td>Moderate (3-6)</td>
<td>29.5</td>
<td>1.69 (1.52-1.88)</td>
</tr>
<tr>
<td>High (≥7)</td>
<td>35.4</td>
<td>2.04 (1.86-2.22)</td>
</tr>
<tr>
<td></td>
<td>P trend &lt;0.001</td>
<td>P trend &lt;0.001</td>
</tr>
</tbody>
</table>

RR (95%CI) = Risk Ratio (95% confidence interval).
Multivariate RR were adjusted for school, gender, grade, perceived health and family affluence
Table 4. Multivariate associations in the longitudinal study

<table>
<thead>
<tr>
<th>Physical activity level in school (hrs per week)</th>
<th>Normal Weight RR (95% CI)</th>
<th>Overweight/Obese RR (95% CI)</th>
<th>P value for interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (&lt;3)</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Moderate (3-6)</td>
<td>1.26 (0.71-2.23)</td>
<td>1.00 (0.45-1.53)</td>
<td></td>
</tr>
<tr>
<td>High (≥7)</td>
<td>1.42 (0.79-2.48)</td>
<td>1.10 (0.65-1.50)</td>
<td>p = 0.70</td>
</tr>
<tr>
<td></td>
<td>P trend = 0.03</td>
<td>P trend = 0.45</td>
<td></td>
</tr>
<tr>
<td>Physical activity level outside of school (hrs per week)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Low (&lt;3)</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Moderate (3-6)</td>
<td>1.77 (1.38-2.22)</td>
<td>1.46 (0.76-2.47)</td>
<td></td>
</tr>
<tr>
<td>High (≥7)</td>
<td>2.82 (2.34-3.30)</td>
<td>1.83 (1.07-2.80)</td>
<td>p = 0.07</td>
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<tr>
<td></td>
<td>P trend &lt;0.001</td>
<td>P trend &lt;0.001</td>
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</tr>
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</table>

RR (95%CI) = Risk Ratio (95% confidence interval).
RR were adjusted for school, gender, grade, perceived health and family affluence
**Figure 1:** Conceptual framework for planned analyses. In this study, BMI status of young people was hypothesized to modify the relationship between engagement in physical activity and the occurrence of associated physical activity injury.
References


37. Karsten L. *It all used to be better? Different generations on continuity and change in urban children's daily use of space.* Child Geo 2005. 3(3): 275-90.
Do overweight and obese youth take longer to recover from injury?

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Total word count (Abstract): 194
Total word count (text only): 1922
Number of pages: 21
Number of tables: 3
Number of figures: 1

Short title: Obesity and recovery from injury in youth

Funding: This research was funded by the Ontario Graduate Scholarship (OGS), a Canadian Institutes of Health Research (CIHR) grant (Grant: MOP 394-791) and a CIHR Banting and Best Master’s Award to the primary author.

Conflict of interest: None

Key Words: Obesity, Injury, Recovery, Youth, Population Health.
Abstract

Objective: To examine the effects of overweight and obesity on times to recovery among Canadian youth who have suffered one or more sentinel types of injury.

Design: The data source was the 2002 Canadian Health Behaviour in School-Aged Children (HBSC) survey. The study population included 7266 youth in grades 6 through 10 sampled from all Canadian provinces and territories. Of these, 2831 students reported an injury event and were included in the analysis. Kaplan-Meier curves and hazard ratios were used to profile survival functions and estimate relative hazards for non-recovery from sentinel injury events among normal, overweight and obese youth.

Results: Youth who were obese and suffered a combined injury (broken bone and strain/sprain) took longer to recover (HR 1.81, 95% CI 0.99-3.32) compared to normal weight youth. Hazard ratios for injury recovery in obese youth were not significantly elevated for broken bones (HR 1.15, 95% CI 0.61-2.19) and sprain/strains (HR 1.17, 95% CI 0.73-1.85) in isolation.

Conclusions: Obesity was found to influence times for injury recovery among injured youth. Clinicians providing an injury recovery prognosis may need to take into account BMI status and allow for extra recovery time for overweight and obese youth.
Introduction

Long-term consequences of pediatric obesity are well understood in terms of risks for chronic diseases. Within children and youth, obesity can lead to alterations in blood cholesterol levels [1], high blood pressure [1], and glucose intolerance, leading to cardiovascular disease and type 2 diabetes later in life [2]. Obesity is associated with several immediate health and social problems in young people including sleep apnea [2], joint problems [3], reduced self esteem [4], and problems with peer relations [5]. Recently, attention has also been given to the impact of obesity on the occurrence [6, 7] and recovery [3, 8, 9] from injury.

In a study of 316 youth, increased risks of complications (41% vs 22%) and a greater recovery time (8 ± 9 vs 6 ± 6 days) following severe medical trauma were observed within obese compared to normal weight participants [10]. Two other small clinical studies reported that obese children experience increased complications related to femoral fractures [9], as well as more persistent pain, swelling and re-injury following an ankle sprain [3]. Existing research on this topic is limited due to the use of relatively small convenience samples, its focus on single injury types, and use of non-conventional measures of BMI status.

Population-based research that employs standard BMI measures and examines multiple injury types is required to describe the overall effects of obesity on recovery from injury among youth. Such a study is important for several reasons. First, both obesity [11] and injury [12] are highly prevalent within young people. Second, prolonged times of recovery lead to delayed return to school and normal activities.
Identification of specific risk factors for longer recovery inform treatment and patient management plans made by clinicians [13].

The purpose of this analysis was to examine the effects of overweight and obesity on the time to recovery within youth who have suffered specific types of injury. It was hypothesized that obese youth who suffered an injury would take significantly longer to recover than those with a healthy weight. We had the opportunity to explore these relationships using existing, population health data obtained on a large and representative sample of Canadian youth in grades 6 to 10.

Methods

Design

The study involved a cross-sectional analysis of the 2002 Canadian Health Behaviour in School-Aged Children (HBSC) survey [14]. This survey was conducted in collaboration with the World Health Organization and followed an international protocol [15]. HBSC employs a cluster design, with randomly selected classrooms from public and separate school boards reflecting provincial distributions of schools by size, location, language, and religion [15]. Youth attending private, special-need, home, incarcerated or street youth school programs are excluded. These represent less than 10% of the youth population within Canada [16]. Self-reported information describing demographic and psychosocial factors, health behaviours, home school and neighborhood settings, and health outcomes was collected from all participants.
The 2002 Canadian HBSC involved 7266 youth in grades 6 through 10, from 188 public schools sampled from all provinces and territories. Of these, 3958 (54%) students reported one or more injury event. In addition to those students who did not report an injury event, students were excluded due to incomplete information on BMI (n=674), physical activity (n=197), and injury mechanism (n=256), leaving 2831 students (72% of those injured) available for analysis. Those who were excluded tended to be younger and a higher percentage were female (data not shown).

**Exposure (BMI)**

The body mass index (BMI), calculated as weight in kg divided by height in m\(^2\) (kg/m\(^2\)), is the most commonly used index of BMI status among youth [12]. International age and gender-specific BMI standards for youth were used to classify participants as being normal weight, overweight, or obese [17]. Growth curves have been created for use in calculating BMI status in youth where at age 18, the curves pass through the adult cut-off points of 25 (overweight) and 30 kg/m\(^2\) (obese) [17]. The use of self-reported BMI is reported reliably [18, 19] and there are high correlations between estimated BMI and actual weight [18, 19]. However, self-reported BMI tends to under-predict the prevalence of excess BMI in youth [20].

**Injury Outcomes**

An initial question that stated “During the past 12 months, how many times were you injured and had to be treated by a doctor or nurse” was used to identify injury events. Injuries were classified into 4 groups based upon their biomechanical significance; (1) *broken bones*, including those that were broken, dislocated or out of joint; (2) *sprains/strains*, which included sprains, strains, or pulled muscles and (3)
combined injuries, which includes broken bones and strains/sprains that occurred during the same injury event; and (4) any other injuries.

Information on recovery from injury was inferred from a proxy measure, where the injured participant indicated the number of days missed from school or other usual activities for the one most serious injury. Loss of activity from a medically treated injury provides one standard indicator of injury severity [21] to separate minor injuries from major ones [22].

Confounders

Variables considered a priori as potential confounders were physical activity, grade, gender, socioeconomic status, and perceived health. Questions on physical activity asked about the number of days over the past week and then a typical week that the student was physically active for at least 60 minutes per day. Responses ranged from 0 to 7 days and were averaged to create a summary measure. Physical activity items in the HBSC have been found to overestimate physical activity levels [15], but have adequate reliability and validity [23, 24].

Justifications for additional confounders follow. There are less overweight and obese females than males [11] and gender differences in injury recovery have been reported [25, 26]. Similarly, older youth have higher rates of obesity [11] and age is a factor in injury recovery [27]. Socio-economic status is related to both BMI [4] and injury recovery [28]. A 3-point Family Affluence Scale was used to infer family socioeconomic status. This scale examines vehicle and computer ownership, bedroom sharing, and holiday travel [29] and scores reported by students are similar to their parents' reports of socio-economic status [29]. General health status was inferred from a
question on self-rated health that asks participants to report if their health is excellent, good, fair or poor. This is also important as youth are known to have poor BMI status if they are not healthy [30, 31] and individuals with health complications take longer to recover from injury [9].

Analysis

All statistical analyses were performed using SAS version 9.1 (SAS Institute, Cary NC). Descriptive analyses were used to characterize the distribution of key variables. Kaplan-Meier curves and the log rank test were used to profile the survival functions for recovery from various type of injury. Cox proportional hazard regression models were used to estimate the relative hazards for non-recovery from injury between injured youth from various BMI groups. Cox models assume proportional hazards, unbiased censoring and linearity in the data which was checked before the model was employed. A backward stepwise selection procedure was employed to confirm a parsimonious set of confounders for the Cox regression models. Grade and gender were forced into the models as they are known confounders [32], while physical activity, perceived health and family affluence were also entered but subsequently removed based on changes of less than 10% in the main effects with and without including the covariates [33]. Results from the proportional hazard regression models are presented as hazard ratios (HR) and their associated 95% confidence intervals (CI).
Results

The sample of injured participants is described in Table 1. The majority of youth had a normal weight (80.8%). Most of the reported injuries were strains/sprains (47.7%) with 16.2% reporting combined injuries.

Table 2 summarizes the associations between BMI status and various descriptors of injury. In each BMI category, youth were most often injured 1 time, the injury was most often a strain/sprain, and they typically did not miss more than 1 day of school or normal activity due to the injury event.

Figure 1 displays that Kaplan-Meier curves that illustrate recovery from injury by BMI status for the main injury outcomes. There were no apparent differences found across BMI categories for the isolated injury types including broken bones alone ($P = .67$), sprains and strains alone ($P = .99$), and other injuries ($P = .31$). Recovery took longer for overweight and obese youth who suffered a combined injury that included a broken bone and a sprain/sprain ($P = .06$).

Table 3 describes the hazard ratios (HR) and associated 95% confidence intervals (CI) for injury recovery for each injury type according to BMI status. In comparison to normal weight youth, obese youth had similar recovery times for broken bones (HR 1.15, 95% CI 0.61-2.19) and sprain/strains (HR 1.17, 95% CI 0.73-1.85). Overweight and obese youth who suffered a combined injury (broken bone and sprain/strain) had increased injury recovery length as compared to normal weight youth (overweight - HR 1.22, 95% CI 0.86-1.73; obese - HR 1.81, 95% CI 0.99-3.32).
Discussion

Findings from this study suggest that obese youth who suffer an injury may take longer to recover than injured youth of normal weight. Obesity appeared to have an important effect on recovery from combined injuries, which are likely injuries that are more severe in nature than the individual injury types.

The findings are consistent with existing biomedical research. In the past, overweight and obese youth have reported taking longer to recover following severe medical trauma [10]. They also report increased risks for persistent pain, swelling and re-injury following occurrence of an ankle injury [3].

An impaired course of recovery following injury in obese children may be explained by several factors. Functional and structural limitations imposed by obesity may result in improper lower limb mechanics and the potential for musculoskeletal re-injury [34]. Obesity leads to increases in weight-bearing forces on the joints, especially to the lower limbs [35]. Obesity also causes problems with blood flow [36] and metabolism in youth [4]. Overweight and obese youth may be less likely to exercise during injury recovery which effects return to normal activity [37]. It is also possible that the severity of injuries may be greater in obese youth. The combined injuries may have been caused by stronger weight-generated forces among obese children, with increased torque on bones that potentially magnified the amount of damage.

Strengths of this study warrant comment. The HBSC is a large and robust survey that is purported to be representative of Canadian youth [15]. This specific analysis was guided by theory, a practice that is uncommon in injury research.
Limitations of this study included the self-reported nature of the data collection. Injury recovery was measured in the HBSC for the one most serious injury event that occurred to youth throughout a one-year period. This is problematic as youth may be have multiple injuries which would not be captured. This analysis is subject to errors in recall and a subjective assessment of injury severity by youth. This may have caused non-differential misclassification and biased the results towards the null. No items were available on anatomical locations of injury. That information would have permitted more focused sub-analyses by nature and anatomical site. There may also be a selection bias in that children who did not attend school on the day of survey administration would not be included in the sample. These could potentially be the most injured participants and that is why they were absent from school. This group at the extreme is important and would be lost in this analysis.

Furthermore, the participants in this study may have returned to school or normal activity before they were completely healed. Recovery time, as measured in this study, may have been confounded by other factors that were not controlled for such as family support, activity type, nutrition, previous injury and body biomechanics. For example, family support and access to transportation may affect the length of time before a youth returns to school. A supportive family may keep a child home longer to ensure healing or follow the guidelines prescribed by a physician more effectively [3]. Transportation is another key variable that could affect the results [10]. A child with a broken leg, for example, could potentially return to school faster with parents who drop them off at school. Walking or taking the bus might be more difficult and a longer recovery time may be necessary to return to school. The return to school variable is limited due to the lack of
control on such variables. All of these factors could have lead to misclassification, washing out any effects that may have been found.

Students for this analysis were clustered at the school level. Clustering in the data set was not accounted for using multilevel modeling. Multilevel for time to event data is an extremely difficult statistical process and was not performed here. Therefore the confidence intervals may be slightly wider than those found.

There is an expanding list of health consequences to youth that are associated with obesity. Obesity leads to poor health outcomes which may include recovery from injury. Results of this analysis are important for clinicians, especially those in emergency departments and medical clinics, who inform youth of their expected recovery time following injury. BMI status is currently not considered when determining an injury recovery prognosis [38]. Overweight and obese youth may take longer to recover and therefore recommendations on return to activity should coincide with appropriate healing to prevent re-injury and to plan optimal management for patients. Continual research should be performed to determine the specific relationship between BMI status and recovery from injury.

**KEY MESSEGES**

*What is already known on this subject*

- The prevalence of obesity is continuing to rise in youth and causes numerous short and long term health problems.
• There is recent interest in the impact of BMI on short-term health outcomes, including injury risk and recovery.

*What this study adds*

• Obese youth who suffer a major injury take longer to recover than normal weight youth.

**Acknowledgements**

This study was supported financially by the Canadian Institutes of Health Research (Grant: MOP 394-791) and the Public Health Agency of Canada (Contract: HT089-05205/001/SS) which funds the Canadian version of the *Health Behaviour in School-Aged Children Survey*; a World Health Organization / European Region collaborative study. International Coordinator of the 2005/2006 study: Candace Currie, University of Edinburgh; Data Bank Manager: Oddrun Samdal, University of Bergen.

This publication reports data solely from Canada (Principal Investigator: William Boyce). Ian Janssen was funded by a New Investigator Award from CIHR and an Early Researcher Award from the Ontario Ministry of Research and Innovation. Joel Warsh was funded by the Ontario Graduate Scholarship and a CIHR Banting and Best Master’s award.
Contributorship

Each of the authors has met the criteria for authorship. Joel Warsh contributed to the study design, analysis and drafting of the paper. Ian Janssen and William Picket contributed to the conceptual framework, study design, acquisition, analysis and interpretation of the data and drafting and critical revision of the manuscript. All of the authors approved the final version of the manuscript.

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References


38. Brison R. Emergency Medicine, Kingston General Hospital. April 22, 2009 (Personal communication).
Table 1. Descriptive characteristics of the sample of Canadian students reporting medically treated injuries (n=2831)

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
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<td><strong>Gender</strong></td>
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<td>Female</td>
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<tr>
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<td>School Health Service</td>
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Table 2. Analysis of number of injuries, injury type and injury recovery by BMI status, 2002 sample of Canadian students reporting medically treated injuries

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<tr>
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<th>Normal (n=2287)</th>
<th>Overweight (n=435)</th>
<th>Obese (n=109)</th>
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<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Total Times Injured in 12 Months</td>
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<tr>
<td>1</td>
<td>44.6</td>
<td>40.4</td>
<td>43.1</td>
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<tr>
<td>2</td>
<td>27.1</td>
<td>28.9</td>
<td>26.6</td>
</tr>
<tr>
<td>3+</td>
<td>28.3</td>
<td>30.7</td>
<td>30.8</td>
</tr>
<tr>
<td>Injury Type</td>
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<td></td>
</tr>
<tr>
<td>Sprain/Strain</td>
<td>47.6</td>
<td>47.8</td>
<td>49.5</td>
</tr>
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<td>Broken Bone</td>
<td>13.4</td>
<td>12.4</td>
<td>13.8</td>
</tr>
<tr>
<td>Broken Bone and Sprain/Strain</td>
<td>16.5</td>
<td>15.4</td>
<td>13.8</td>
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<tr>
<td>Other</td>
<td>22.6</td>
<td>24.4</td>
<td>22.9</td>
</tr>
<tr>
<td>Injury Recovery - Broken Bone (days)</td>
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<td></td>
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<tr>
<td>0</td>
<td>41.8</td>
<td>46.3</td>
<td>33.3</td>
</tr>
<tr>
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<td>7.4</td>
<td>13.3</td>
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<td>11.1</td>
<td>11.1</td>
<td>13.3</td>
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<tr>
<td>30+</td>
<td>5.2</td>
<td>3.7</td>
<td>6.7</td>
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<tr>
<td>30+</td>
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<td>1.4</td>
<td>0.0</td>
</tr>
<tr>
<td>Injury Recovery- Combined Injuries (days)</td>
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<tr>
<td>0</td>
<td>41.4</td>
<td>44.8</td>
<td>26.7</td>
</tr>
<tr>
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<td>14.3</td>
<td>7.5</td>
<td>6.7</td>
</tr>
<tr>
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<td>29.7</td>
<td>31.3</td>
<td>26.7</td>
</tr>
<tr>
<td>8 to 30</td>
<td>11.1</td>
<td>13.4</td>
<td>20.0</td>
</tr>
<tr>
<td>30+</td>
<td>3.4</td>
<td>3</td>
<td>20.0</td>
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<tr>
<td>Injury Recovery – Other Injury (days)</td>
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<td></td>
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<tr>
<td>0</td>
<td>70.2</td>
<td>56.6</td>
<td>60.0</td>
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<td>1</td>
<td>10.9</td>
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<td>2 to 7</td>
<td>12.6</td>
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<td>20.0</td>
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<td>5.6</td>
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<tr>
<td>30+</td>
<td>0.8</td>
<td>0.9</td>
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</table>
Table 3. Hazard ratios and associated 95% confidence intervals for non-recovery from injury according to BMI status

<table>
<thead>
<tr>
<th>Injury category</th>
<th>Normal Weight</th>
<th>Overweight</th>
<th>Obese</th>
<th>P Trend</th>
</tr>
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<tbody>
<tr>
<td>Broken Bone</td>
<td>1.00</td>
<td>1.15 (0.77-1.71)</td>
<td>1.15 (0.61-2.19)</td>
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<tr>
<td>Sprain/Strain</td>
<td>1.00</td>
<td>0.97 (0.78-1.21)</td>
<td>1.17 (0.73-1.85)</td>
<td>0.33</td>
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<tr>
<td>Broken Bone and Sprain/Strain</td>
<td>1.00</td>
<td>1.22 (0.86-1.73)</td>
<td>1.81 (0.99-3.32)</td>
<td>0.07</td>
</tr>
<tr>
<td>Other Injury</td>
<td>1.00</td>
<td>0.86 (0.61-1.19)</td>
<td>0.86 (0.45-1.64)</td>
<td>0.81</td>
</tr>
</tbody>
</table>

Hazard ratios are adjusted for age and sex
Figure 1: Kaplan Meier Curves of recovery after injury

Survival curves of non-recovery; (A) Combined injury (B) Sprains/Strains; (C) Broken Bones
Chapter 5: General Discussion

5.1 Summary of Key Findings and Contributions

The purpose of this thesis was to investigate the effects of BMI on the occurrence of, and also recovery from, unintentional injuries among Canadian youth. The major finding of the first manuscript was that BMI did not modify the relationship between physical activity and physical activity injury in Canadian youth. Because associations were consistent in normal weight and obese youth, special safety precautions such as separating groups according to BMI status within physical activity classes, or the provision of special equipment during such activities, do not appear to be warranted for obese children. Further, existing pediatric obesity treatment guidelines recommend that obese youth engage in at least an hour of moderate intensity physical activity on a daily basis. [1] It is unclear whether this would put obese children at elevated risks for injury. Our study findings suggest that program administrators and coordinators involved in such interventions can expect young people to participate in such programs that facilitate physical activity without facing undue risks.

Results from the second manuscript demonstrated that obese youth who suffer a combined injury (an injury that combines a fracture with a sprain or strain), which likely represents more severe injuries, take longer to recover than normal weight youth. This suggests that obesity may have important effects on recovery from injury in young people. Clinicians should therefore consider BMI status when describing prognoses for
recovery from injury among this age group. Speculatively, it may be prudent for health professionals to be somewhat more cautious with overweight and obese youth to prevent re-injury. By extending the times and prognoses for these youth, it may allow healing to occur prior to return to normal activity.

### 5.2 Strengths and Limitations of the Thesis

HBSC is a large and robust survey which involves collection of data from young people from across the country. It is purported to be representative of the health and health experiences of Canadian youth [2]. HBSC provides data on a wide range of health behaviours, health outcomes and contextual measures on determinants of health. The health and experiences of Canadian youth are felt to be similar to child populations in many industrialized nations. Similarly, the experiences of young people in Ontario (focus of part of this study), while not representative of the rest of the country, come from a large and diverse population. Associations between obesity and injury should be representative of Ontario high school children, and perhaps beyond. These are strengths of the current study.

Second, the analyses conducted in this study were guided by theory, a practice that is uncommon in injury research. A theoretical framework was developed in order to conceptualize relationships between injuries, physical activity and BMI, and relationships were studied within that framework. Intentional use of this framework represents an advance in thinking.

Determination of potential cause and effect relationships represents a goal of most epidemiological research projects. Standard criteria for causation include temporality,
consistency, biological plausibility, dose response, and the strength and statistical
significance of observed relationships.

Temporality, one of the central postulates of causality, was explored in manuscript 1
through the use of a longitudinal confirmation of findings initially identified cross-
sectionally. Manuscript 2 used only cross-sectional data but had an outcome that involved
time to an event. Temporality could not be fully explored in this situation but it is
unlikely that a youth would change BMI categories following an injury within the 1 year
time frame of this study. The temporal sequence is therefore unlikely to be effected by
the cross-sectional data obtained.

With respect to biologically plausibility, both studies were designed from a
biological framework. The results fit in to a larger continuum of research on injury and
obesity that demonstrates that there is a significant relationship between these two
variables. Findings from our study were consistent with the literature on BMI and
injuries. BMI is generally found to have significant effects on injuries in you. Our results
should be viewed within the wider context of research.

Dose-response was observed between risks for injury and amount of physical
activity. The higher the level of physical activity, the more likely a youth was to become
injured. Strength and statistical significance were determined by testing the focal
relationships of interest.

Common forms of bias warrant consideration in this study. Selection bias may
have been an issue in this population. Selection bias occurs when participants are selected
in a manner that causes an effect on the focal relationship of interest where participants
are selected in a way that would have modified the relationship found between physical
activity and injury. Students not included in the survey may have differed with respect to
the relationships explored. For example, it is possible that youth who were away at the
time of survey administration may have been injured and not available in order to take
the survey. More obese youth could have been absent on the day of administration as
obese youth take longer to recover than normal weight youth and therefore the
relationship of interest could be compromised. If a section of the most obese youth were
missing and they in fact take longer to recover, the results in our manuscript would be
biased towards the null masking a true relationship.

Information bias is another key issue of to consider in the interpretation of this
study. Both studies used self-reported survey data which is subject to errors in recall and
also potential recall bias. In youth, physical activity levels are known to be overestimated
while BMI levels are often underestimated. This would lead to non-differential
misclassification of participants and ultimately bias results towards the null. This was
minimized through the use of tested tools [3, 4].

Normal weight youth and overweight/obese youth had a slightly different pattern
of physical activity. Normal weight youth had a higher percentage of moderate
physically active as compared to overweight/obese youth. Higher levels of physical
activity are related to increases in injury and therefore differing patterns of physical
activity between the normal and overweight/obese youth may have affected the results.

In manuscript 2, injury recovery was measured only for the one most serious
injury that occurred to the student. Information on all injuries would be ideal as this
would provide more complete information on such injuries to youth. Multiple severe
injuries during a school year that are completely separate events should each be
considered; however, this was not possible based upon the HBSC survey design. Students may also not be fully healed when returning to school so a full picture of the injury experience is not possible without unbiased medical information. This quick return would lead to inaccurate measures of recovery in our study.

5.3 Future Research Directions

Few studies have examined the effects of BMI on injury occurrence and recovery. From the results, it is clear that further research is warranted. Manuscript 1 found no modifying effects of BMI status on the relationship between physical activity and physical activity injuries. This research should be replicated, looking at other types of injuries including neurologic events, falls and injury-related fatalities to determine if the focal relationship holds true in different situations. These relationships would also be important to examine in other populations including adults and seniors. Physical activity is used in the treatment and prevention of injuries in most populations and therefore an understanding of its effects on injury are important to program planning in populations other than youth. More extreme levels of obesity should also be examined in similar analyses. This study did not have the statistical power to look at variations in injuries at extreme levels of obesity, and hence we combined the groups of overweight and obese. It is possible that this combined group was not an extreme enough BMI group to see meaningful effects.

In manuscript 2 there was a clear relationship between BMI status and injury recovery. A large scale, prospective study would be important to fully explore the effects of BMI
on recovery. It should include the use of medical records and follow-up of individual students over time. This is required to provide accurate measures of the increased recovery time experienced by obese youth. A study should look at all injuries experienced by youth across a year or longer, and not just the single most serious injury as in our study. This research should also be replicated in other populations including adults and seniors, as injury recovery may differ across populations based on changing body biomechanics, bone density and strength.

5.4 Public Health and Policy Implications

Our analyses showed that BMI status in youth did not modify the relationship between physical activity and physical activity injuries, while it did effect time to recovery following injury. Obesity is a major public health concern for youth and unintentional injury is the largest cause of mortality in youth [5]. Therefore the association between these two variables needed to be explored. With the number of overweight and obese youth continuing to rise, negative effects of obesity will be magnified [6]. Appropriate prevention strategies for obesity are important and physical activity is generally regarded as a cornerstone of the weight loss action plan [7, 8]. All youth should take part in physical activity programs as overweight youth were not at any increased risk of physical activity injury in comparison to normal weight youth. Safety precautions should be taken for all youth as physical activity is the leading cause of injury, but the risks appear to be uniform across BMI groups.
However, BMI status did influence time to recovery for injured youth. Overweight and obese youth who suffered a combined injury took longer to recover than normal weight youth. Several mechanisms have been proposed to account for these differences including poor nutrition and health practices, body biomechanics, and excess forces on the body [9-11]. When presented with an injury such as a fracture or sprain/strain, a clinician’s main goal is to heal the child and have them return to normal activity as quickly and safely as possible. A large percentage of injury events are in fact re-injuries, and therefore a clinician must make an accurate prognosis of the rest time needed until the youth has fully recovered. Longer recovery time in obese youth demonstrated that clinicians may need to take into account BMI status when providing a prognosis and treatment plan to injured patients. If similar recovery time is given to normal and obese youth, the obese youth may be vulnerable to re-injury as they have not fully healed.

References


Appendices

Appendix A - HBSC Survey Methodology

The research from this thesis involved analyses of data from the 2006 and 2002 Canadian *HBSC*. In the 2006 HBSC, a total of 9672 students participated from 188 schools across all provinces and territories. The 2002 Canadian HBSC involved 7266 youth in grades 6 through 10, from 188 public schools sampled from all provinces and territories. This survey employs a cluster design, with randomly selected classrooms from public and separate school boards reflecting provincial distributions of schools by size, location, language, and religion.

Using school directories and lists, the number of classes in schools was estimated based on the number of teachers, the total student enrolment, enrolment by grade, and number of grades in the school. Classes were selected based on school jurisdiction, province, language, public/Roman Catholic designation, community size, and community location, giving classes an approximately equal probability of being selected. Youth attending private, special-needs, or home schools were excluded, as were institutionalized, incarcerated, or homeless youth.

Approximately 75% of students in the sample participated, of which less than 10% declined participation or spoiled the questionnaire. Other non-participants were students who failed to return the parental consent form, who did not receive parental consent, or who were absent from school when the survey was administered. Teachers administered the survey. It is a 40 minute written process done during class time, usually in the student’s normal classroom. The survey in unsigned.
## Appendix B – Key HBSC Questions

### Physical Activity

<table>
<thead>
<tr>
<th>Q1</th>
<th>Over the past 7 days, on how many days were you physically active for a total of at least 60 minutes per day?</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0-7 days</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q2</th>
<th>OUTSIDE SCHOOL HOURS: How often do you usually exercise in your free time so much that you get out of breath or sweat?</th>
</tr>
</thead>
<tbody>
<tr>
<td>A2</td>
<td>Every day, 4-6/week, 2-3/week, 1/week, 1/month, &lt;1/month, never</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Q3</th>
<th>OUTSIDE SCHOOL HOURS: How many hours a week do you usually exercise in your free time so much that you get out of breath or sweat?</th>
</tr>
</thead>
<tbody>
<tr>
<td>A3</td>
<td>None, 1/2 hour, 1 hour, 2-3 hours, 4-6 hours, 7+</td>
</tr>
</tbody>
</table>

### Injury Questions from 2005/2006 Survey

<table>
<thead>
<tr>
<th>Q1</th>
<th>During the past 12 months, how many times were you injured and had to be treated by a doctor or nurse?</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Not injured, 1, 2, 3, 4, 4+</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q2</th>
<th>Where were you when this one most serious injury happened?</th>
</tr>
</thead>
<tbody>
<tr>
<td>A2</td>
<td>not injured, home, school during school hours, after school, sports facility, street, other</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q3</th>
<th>What were you doing when this one most serious injury happened?</th>
</tr>
</thead>
<tbody>
<tr>
<td>A3</td>
<td>Bike, playing, skating, walking, running, car, fighting, work, other</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q4</th>
<th>Where were you treated for this one most serious injury?</th>
</tr>
</thead>
<tbody>
<tr>
<td>A4</td>
<td>Not injured, doctor, ER, Hospital, school health, other</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q5</th>
<th>Did this one most serious injury need medical treatment such as the placement of a cast, stitches, surgery, or staying in a hospital overnight?</th>
</tr>
</thead>
<tbody>
<tr>
<td>A5</td>
<td>Not injured, yes, no</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q6</th>
<th>Did this one most serious injury cause you to miss at least one full day from school or other usual activities, such as sports or lessons?</th>
</tr>
</thead>
<tbody>
<tr>
<td>A6</td>
<td>Not injured, yes and number of full days, no activity lost</td>
</tr>
</tbody>
</table>

### Additional Injury Question From 2001/2002 Survey

<table>
<thead>
<tr>
<th>Q7</th>
<th>What were the main results (damage to the body) of this one most serious injury?</th>
</tr>
</thead>
<tbody>
<tr>
<td>A7</td>
<td>Not injured, broken bones sprain, cut, concussion, bruises, internal injury, burn, other</td>
</tr>
</tbody>
</table>

### Body Mass Index

<table>
<thead>
<tr>
<th>Q1</th>
<th>How much do you weigh without clothes?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q2</td>
<td>How tall are you without shoes?</td>
</tr>
</tbody>
</table>

Q - Question; A – Answer choices
## Height & weight (BMI)

**M Q9.** How much do you weigh without clothes? .......................... ........................

**M Q10.** How tall are you without shoes? .......................... ........................

*Source: HBSC surveys 1997/98 (optional package), 2001/02 (mandatory).*

### M Q12.

Physical activity is any activity that increases your heart rate and makes you get out of breath some of the time.

Physical activity can be done in sports, school activities, playing with friends, or walking to school.

Some examples of physical activity are running, brisk walking, rollerblading, biking, dancing, skateboarding, swimming, soccer, basketball, football, & surfing. *[COUNTRY SPECIFIC EXAMPLES CAN BE GIVEN]*

For this next question, add up all the time you spent in physical activity each day.

Over the past 7 days, on how many days were you physically active for a total of at least 60 minutes per day?

<p>| | | | | | | | |</p>
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</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

**M Q14.** OUTSIDE SCHOOL HOURS: How many hours a week do you usually exercise in your free time so much that you get out of breath or sweat?

1. None
2. About half an hour
3. About 1 hour
4. About 2 to 3 hours
5. About 4 to 6 hours
6. 7 hours or more


---

**Prevalence of injuries**

**M Q28.**

Many young people get hurt or injured from activities such as playing sports or fighting with others at different places such as the street or home. Injuries can include being poisoned or burned. Injuries do not include illnesses such as Measles or the Flu. The following questions are about injuries you may have had during the past 12 months.

During the past 12 months, how many times were you injured and had to be treated by a doctor or nurse?

1. I was not injured in the past 12 months
2. 1 time
3. 2 times
4. 3 times
5. 4 times or more

If you had more than one injury, think only about the one most serious injury that you had during the past 12 months that was treated by a doctor or nurse. The next questions are about your one most serious injury (the injury that took the most time to get better). If you were not injured, answer “I was not injured in the past 12 months” for each question.

VIP 1.1 **Where were you when this one most serious injury happened?**
(Check the one best answer to describe your most serious injury)
1) I was not injured in the past 12 months
2) At home/in yard (yours or someone else’s)
3) School, including school grounds
4) At a sports facility or field (not at school)
5) In the street/road/parking lot
6) At a commercial/business area (such as a restaurant, shopping mall, cinema, etc.)
7) Countryside (such as a lake, beach, forest, park etc.)
8) Other location: write it here ________________________________

VIP 1.2. What were you doing when this one most serious injury happened?
(Check the one best answer to describe your most serious injury)
1) I was not injured in the past 12 months
2) Biking/cycling
3) Playing or training for sports/recreational activity
4) Specify sport or activity: (example: football, track, gymnastics, trampoline)
5) Riding a skate scooter
6) Skating (including roller blades, skateboards, ice skating)
7) Walking/running (not for a sports team or exercise)
8) Riding/driving in a car or other motor vehicle
9) Fighting
10) Paid or unpaid work
11) Other: write it here ________________________________

VIP 1.4 Where were you treated for this one most serious injury?
(Check “yes” or “no” for each line)
a) I was not injured in the past 12 months - Go to the next question
b) Doctor’s office/health clinic
c) Emergency room
d) Hospital admission overnight
e) School health service
f) Other: write it here ________________________________

VIP 1.6 What were the main results (damage to the body) of this one most serious injury? (Check “yes” or “no” for each line)
a) I was not injured in the past 12 months - Go to the next question
b) Bone was broken, dislocated or out of joint (includes broken/chipped teeth)
c) Sprain, strain, or pulled muscle
d) Cuts, puncture, or stab wound
e) Concussion or other head or neck injury, knocked out, whiplash
f) Bruises, black and blue marks, or internal bleeding
g) Internal injury requiring an operation
h) Burns
i) Other: write it here ____________________________

VIP 1.5 Did this one most serious injury cause you to miss at least one full day from school or other usual activities, such as sports or lessons?
1) I was not injured in the past 12 months
2) Yes, lost at least one day of activity
How many full days did you miss? ________
(Please write the number of full days you missed from school or other usual activities as a result of this one most serious injury.)
3) No, did not lose a day of activity
Appendix C - Power Calculations

For manuscript #1, power calculations were performed looking at the effect of BMI on the relationship between physical activity and physical activity injury. Power has been estimated based on classical power calculations, adjusting for the HBSC design effect. Since multi-level modeling is a relatively new technique, there is no standard way to calculate power. The design effect takes into account the clustered nature of the data when calculating the sample size, as the clustering will erroneously reduce the standard error.

For manuscript 1, power was calculated using a clinically significant relative risk of 2.0. The calculation uses a sample size that is divided in half to account for the interaction effects of BMI on the relationship between physical activity and physical activity injuries. The test is sufficiently powered (above 90%) outside of school in all cases and in school in the overweight and normal categories. The relationship is only moderately powered in obese youth in school as the percentage of youth exposed in this category is extremely low. There was sufficient power for most calculations. Only calculations involving obese youth had moderate power as there was a lower number of students in that group exposed.
### Calculation 1 - N/2 (for interaction effect) and a clinically significant strong effect (RR of 2.0)

Manuscript 1 -- n total
/2 4810
Nadjusted 1.4 /2 3436
10% data issues /2 3092.5

<table>
<thead>
<tr>
<th>% Exposed</th>
<th>Nexposed</th>
<th>r</th>
<th>RR</th>
<th>p</th>
<th>p0</th>
<th>p1</th>
<th>d</th>
<th>za/2</th>
<th>Z(1-b)</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physically Active Children</td>
<td>Class Time</td>
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<td>96.486</td>
<td>31.05</td>
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<td>0.07</td>
<td>0.14</td>
<td>0.07</td>
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<tr>
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<td></td>
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<td>0.14</td>
<td>0.07</td>
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<tr>
<td></td>
<td></td>
<td>Normal</td>
<td>0.1118</td>
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<td>2</td>
<td>0.08</td>
<td>0.07</td>
<td>0.14</td>
<td>0.07</td>
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<tr>
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<td>Free Time</td>
<td>Obese</td>
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<td>100.197</td>
<td>29.86</td>
<td>2</td>
<td>0.08</td>
<td>0.07</td>
<td>0.14</td>
<td>0.07</td>
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<tr>
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<td>0.14</td>
<td>0.07</td>
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<td></td>
<td>Normal</td>
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<td>359.039</td>
<td>7.61</td>
<td>2</td>
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<td>0.07</td>
<td>0.14</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>Outside of school</td>
<td>Obese</td>
<td>0.0444</td>
<td>137.307</td>
<td>21.52</td>
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<td>0.3</td>
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<td>0.3</td>
<td>0.22</td>
<td>0.44</td>
<td>0.22</td>
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</tbody>
</table>

% Exposed: The percentage of children who physically active by BMI in the general population (Data from Public Health Agency of Canada)

Nexposed: The number of students exposed (i.e. the number expected to be physically active)
r: The ratio of unexposed to exposed (1-% exposed) / % exposed
RR: The detectable Risk (i.e. Risk of injury in high versus low pa group) (Janssen 2006)
p: The proportion of students who have the outcome (Janssen 2006)
p0: The prevalence of physical activity injury in the unexposed (Janssen 2006)
p1: The prevalence of physical activity injury in the exposed (Janssen 2006)
d: The difference between p1 and p0
za/2: The level of significance (using a = 0.05, za/2 = 1.96)

Power:
\[ = F Z_{(1-b)} \]
\[ = F [d [(nr)/p(1-p)(1+r)]] Z_{a/2} \]
Power calculations for manuscript 2 were also calculated using clinically significant values (RR of 2.0). The power to predict the relationship between BMI and injury recovery is high with power calculations above 90% in almost all categories in the 5 days and 1 month groups. Only females at 1 month were moderately powered due to the low percentage exposed in the population. The calculation at 1 year is underpowered due to the low percentage of injury persistence in the exposed and unexposed groups.

Clinically Significant Effect of 2.0

\[ \text{RR} = \frac{P_1}{P_0} \]

\[ \text{RR} = 2.0 \]

Manuscript 2 --

n total 3944
Nadjusted 1.4 2818
10% data issues 2536

<table>
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<th>% Exposed</th>
<th>RR</th>
<th>p</th>
<th>p_o</th>
<th>p_1</th>
<th>d</th>
<th>z_{a/2}</th>
<th>Z_{(1-b)}</th>
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<td></td>
<td></td>
</tr>
<tr>
<td>Obese</td>
<td>Male</td>
<td>0.08</td>
<td>202.88</td>
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<td>2</td>
<td>0.99</td>
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</tr>
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<td>481.84</td>
<td>4.26</td>
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<tr>
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<td>Male</td>
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<td>101.44</td>
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<td>0.04</td>
<td>0.02</td>
<td>1.96</td>
<td>0.02</td>
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<td>481.84</td>
<td>4.26</td>
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<td>0.1</td>
<td>0.05</td>
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<td>6.69</td>
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<td>0.04</td>
<td>0.02</td>
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86
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<th>RR</th>
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<th>p1</th>
<th>d</th>
<th>z_{a/2}</th>
<th>Z_{(1-b)}</th>
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<tr>
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<tr>
<td>Male</td>
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<td>202.88</td>
<td>11.50</td>
<td>2</td>
<td>0.99</td>
<td>0.005</td>
<td>0.01</td>
<td>0.005</td>
<td>1.96</td>
<td>-1.27</td>
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<td>101.44</td>
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<td>0.002</td>
<td>0</td>
<td>0.002</td>
<td>1.96</td>
<td>-1.76</td>
<td>3.91%</td>
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<tr>
<td>Overweight</td>
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<tr>
<td>Male</td>
<td>0.19</td>
<td>481.84</td>
<td>4.26</td>
<td>2</td>
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<td>0.005</td>
<td>0.01</td>
<td>0.005</td>
<td>1.96</td>
<td>-0.97</td>
<td>16.67%</td>
</tr>
<tr>
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<td>0.13</td>
<td>329.68</td>
<td>6.69</td>
<td>2</td>
<td>0.99</td>
<td>0.002</td>
<td>0</td>
<td>0.002</td>
<td>1.96</td>
<td>-1.62</td>
<td>5.27%</td>
</tr>
</tbody>
</table>

% Exposed  The percentage of children who are obese in the general population (Data from Public Health Agency of Canada)

Nexposed  The number of students exposed (i.e. the number expected to be obese)

r  The ratio of unexposed to exposed (1-% exposed) / % exposed

RR  The detectable Rate Ratio (i.e. Rate of injury in obese vs normal weight group) (Zonfrillo 2008)

p  The proportion of students who have the outcome (recovery) (Data from Public Health Agency of Canada http://www.phac)

p0  The prevalence (persistance of injury) in the unexposed (Data from Public Health Agency of Canada http://www.phac)

p1  The prevalence (persistance of injury) in the exposed (Data from Public Health Agency of Canada http://www.phac)

d  The difference between p1 and p0

z_{a/2}  The level of significance (using a = 0.05, z_{a/2} = 1.96)

Power  \[ = \frac{Z_{(1-b)}}{Z_a} \]

\[ = \frac{a}{a} \]
Appendix D - Ethics Approval

QUEEN'S UNIVERSITY HEALTH SCIENCES & AFFILIATED TEACHING HOSPITALS RESEARCH ETHICS BOARD

September 22, 2008

This Ethics Application was subject to:

☐ Full Board Review
Meeting Date:
☒ Expedited Review

Mr. Joel Warsh
Department of Community Health and Epidemiology
Abramsky Hall
Queen's University

Dear Mr. Warsh,

Study Title: The effects of adiposity on the occurrence of and subsequent recovery from physical activity injuries in youth

Co-Investigators: Dr. W. Pickett and Dr. I. Janssen

I am writing to acknowledge receipt of your recent ethics submission. We have examined the protocol for your project (as stated above) and consider it to be ethically acceptable. This approval is valid for one year from the date of the Chair's signature below. This approval will be reported to the Research Ethics Board. Please attend carefully to the following list of ethics requirements you must fulfill over the course of your study:

➢ Reporting of Amendments: If there are any changes to your study (e.g. consent, protocol, study procedures, etc.), you must submit an amendment to the Research Ethics Board for approval. (see http://www.queensu.ca/vpr/reb.htm).

➢ Reporting of Serious Adverse Events: Any unexpected serious adverse event occurring locally must be reported within 2 working days or earlier if required by the study sponsor. All other serious adverse events must be reported within 15 days after becoming aware of the information.

➢ Reporting of Complaints: Any complaints made by participants or persons acting on behalf of participants must be reported to the Research Ethics Board within 7 days of becoming aware of the complaint. Note: All documents supplied to participants must have the contact information for the Research Ethics Board.

➢ Annual Renewal: Prior to the expiration of your approval (which is one year from the date of the Chair's signature below), you will be reminded to submit your renewal form along with any new changes or amendments you wish to make to your study. If there have been no major changes to your protocol your approval may be renewed for another year.

Yours sincerely,

Chair, Research Ethics Board

Date

ORIGINAL TO INVESTIGATOR - COPY TO DEPARTMENT HEAD - COPY TO HOSPITALS / PA/7 (if applicable) - FILE COPY

Study Code: EPID-275-08

➢ Investigators please note that if your trial is registered by the sponsor, you must take responsibility to ensure that the registration information is accurate and complete.