2016-01-29

The Influence of Previous Injury History on Health and Fitness Outcomes in Junior High School Students

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van den Berg, C. (2016). The Influence of Previous Injury History on Health and Fitness Outcomes in Junior High School Students (Unpublished master's thesis). University of Calgary, Calgary, AB. doi:10.11575/PRISM/28216

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The Influence of Previous Injury History on Health and Fitness Outcomes in Junior High School
Students

by

Carla Ann van den Berg

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE
DEGREE OF MASTER OF SCIENCE

GRADUATE PROGRAM IN KINESIOLOGY

CALGARY, ALBERTA

JANUARY, 2016

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Abstract

Objective: To assess the influence of previous sport and recreational injury on body composition, cardiorespiratory fitness, musculoskeletal strength, and dynamic balance in junior high school students (ages 11-16).

Methods: Cross-sectional study design. Participants included 1,039 students from six junior high schools in Calgary, Alberta, Canada. Demographics, injury history, and sport participation over the previous 12 months were collected using a questionnaire. Outcome measures included body mass index (BMI), waist circumference, predicted VO₂max, vertical jump, eyes closed dynamic balance, and star excursion balance test reach distances.

Results: Previously injured participants had significantly higher BMI and left foot balance times compared to uninjured participants. Exploratory analysis results suggest that those who sustained two injuries had a significantly increased BMI and waist circumference compared to those who sustained no injuries.

Conclusions: Participants with a history of injury demonstrated more unhealthy body composition, but better left foot dynamic balance compared to uninjured participants.

Acknowledgements

Firstly, I would like to acknowledge the Calgary Board of Education, the students, and the teachers who participated in the study. This research project would not have been possible without their cooperation and enthusiasm.

I would like to express my sincere gratitude to my supervisors, Dr. Tish Doyle-Baker and Dr. Carolyn Emery, and to my committee members, Dr. Alberto Nettel-Aguirre and Dr. Sarah Richmond. I am incredibly lucky to have had the opportunity to work with all of you. Your guidance, patience, encouragement, and support for this thesis have been invaluable. To have four individuals who are all so dedicated and caring is such a privilege. I have learned so much over the past two years from each of you, and value all of your feedback in the highest regard.

I would also like to acknowledge Maria Romiti. You were an exceptional mentor and, no matter how hectic, always managed to run the testing with a smile on your face. Your positive energy kept us going, and without you the completion of this project would not have been possible.

Thank you to all the research assistants and peers who have spent countless hours helping with this study. Your enthusiasm and hard work were instrumental to the data collection process. To my lab mates at the Sport Injury Prevention Research Centre, I could not have asked for a better group of individuals to work alongside. Your unconditional support, advice, and good humour have made the journey towards my Master's an unforgettable one.

To my St. FX family who have helped me call Calgary home, thank you for always being there to share a laugh, help relieve the stress, and cook me dinner when the going got tough. I am so lucky to have such an incredible group of supportive friends.

Funding for this research study was made possible by funding sources from Alberta Innovates Health Solutions – Collaborative Research and Innovation Opportunities Program Grant, and the Alberta Children’s Hospital Foundation.

Dedication

It is without question that I am dedicating this thesis to my family. To my parents, Ian and Sian, thank you for instilling the values of hard work and dedication. So much of what I learned I owe to you; I would not be where I am today without your unconditional love and support. To my brothers, Ryan and Nicholas; thank you for keeping me grounded, and for never letting me do things the easy way. I look up to both of your passions for research, and always aspire to match your intelligence. Although we are living all over the country, you have still helped shape who I am, and have always been a strong support system. To you I am forever grateful.

Table of Contents

Abstract	ii
Acknowledgements	iii
Dedication	v
Table of Contents	vi
List of Tables	ix
List of Symbols, Abbreviations and Nomenclature	xii
 CHAPTER ONE: INTRODUCTION	 1
1.1 Problem Statement	1
1.2 Research Purpose	2
1.3 Background	2
1.3.1 Sport and Recreational Injury in Adolescents	2
1.3.2 Sport Participation	3
1.3.3 Health and Physical Fitness of Canadian adolescents	3
1.4 Research Question and Specific Objectives	4
1.4.1 Primary Objectives	4
1.4.2 Secondary Objective	5
1.4.3 Exploratory Objectives	5
1.5 Research Rationale	6
1.6 Summary of Thesis Format	6
 CHAPTER TWO: LITERATURE REVIEW	 8
2.1 Introduction	8
2.2 Methods	8
2.2.1 Data Sources	8
2.2.1.1 Search Terms	9
2.2.1.2 Search Strategy	9
2.2.2 Study Selection Criteria	10
2.2.3 Previous injury and balance outcomes	15
2.2.4 Previous injury and performance	18
2.2.5 Previous injury and return to physical activity	20
2.2.6 Previous injury and health status	24
2.2.7 Previous injury and body composition	25
2.2.8 Previous injury and physical fitness outcomes	26
2.3 Conclusion	27
 CHAPTER THREE: METHODS	 28
3.1 Study Design	28
3.2 Study Population	28
3.3 Procedures	32
3.3.1 Data Collection	32
3.3.2 Study Questionnaire	33
3.3.3 Outcome measures	34
3.3.3.1 Body Composition:	34

3.3.3.2 Cardiorespiratory fitness measurement: Predicted VO ₂ max calculated from 20-m shuttle run results.....	36
3.3.3.3 Lower body musculoskeletal strength: Vertical Jump test	37
3.3.3.4 Dynamic Balance	38
3.3.4 Exposure variables.....	41
3.3.5 Previous Sport Participation	41
3.3.6 Injury History	41
3.4 Statistical Methods:.....	42
3.4.1 Descriptive Statistics	42
3.4.2 Bland-Altman Limits of Agreement.....	43
3.4.3 Multivariable Analyses.....	44
3.4.3.1 Primary and Secondary Objectives	44
3.4.3.2 Exploratory Objectives	45
3.5 Ethical considerations	46
CHAPTER FOUR: RESULTS	48
4.1 Study Participants	48
4.2 Previous Sport and Recreational Injury	49
4.2.1 Type of injury	50
4.2.2 Injured body part	50
4.3 Predicted VO ₂ max Agreement between 20-m shuttle run tests.....	51
4.4 Health and Physical Fitness Outcome Measures	53
4.4.1 Crude Analysis	53
4.4.1.1 Descriptive Statistics.....	53
4.4.2 Multivariable Analyses.....	60
4.4.2.1 Primary multivariable logistic regression analyses	60
4.4.2.2 Primary multivariable linear regression analysis.....	63
4.4.3 Exploratory Analyses	68
4.4.3.1 Exploratory multivariable logistic regression analyses	68
4.4.3.2 Exploratory multivariable linear regression analysis.....	69
CHAPTER FIVE: DISCUSSION.....	83
5.1 Participant characteristics and participation	83
5.2 Previous injury.....	84
5.3 Health and Physical Fitness Outcomes	85
5.3.1 Body Composition.....	85
5.3.2 Physical Fitness	88
5.4 Sport participation.....	91
5.5 Strengths	92
5.6 Limitations	94
CHAPTER SIX: CONCLUSION	98
6.1 Summary of Findings.....	98
6.2 Public Health Implications.....	98
6.3 Recommendations for Future Research.....	99
REFERENCES	101

APPENDIX A: SAMPLE SIZE CALCULATION	108
APPENDIX B: CONSENT AND ASSENT FORMS	114
APPENDIX C: PAR-Q+ FORM	123
APPENDIX D: BASELINE QUESTIONNAIRE	128

List of Tables

Table 2.1 Medical subject headings and text words used for article extraction	9
Table 2.2 Summary of literature review results	11
Table 4.1 Participant demographics by previous injury status	49
Table 4.2 Self-reported injury by injury type	50
Table 4.3 Self-reported injury by body part.....	51
Table 4.4 Bland-Altman mean difference and 95% limits of agreement for VO ₂ max estimated by PACER and Léger 20-m shuttle runs	52
Table 4.5 Health outcome measures for injured and uninjured groups stratified by age and sex	56
Table 4.6 Fitness outcome measures for injured and uninjured groups stratified by age and sex	57
Table 4.7 SEBT measures for injured and uninjured groups stratified by age and sex	58
Table 4.8 Odds ratios based on multivariable logistic regression models describing body composition measures (adjusted for sport participation, age, and sex)	62
Table 4.9 Coefficients of injury and means between injured and uninjured participants in multivariable linear regression models describing health outcome measures, adjusted for sport participation, age, and sex.....	65
Table 4.10 Coefficients of injury and means between injured and uninjured participants in multivariable linear regression models describing fitness outcome measures (adjusted for sport participation, age, and sex).....	66
Table 4.11 Coefficients of injury and means between injured and uninjured participants in multivariable linear regression models describing fitness outcome measures (adjusted for sport participation, age, and sex).....	67
Table 4.12 Unadjusted and adjusted odds ratios from exploratory multivariable logistic regression models describing health outcome measures	72
Table 4.13 Unadjusted and adjusted injury coefficients from exploratory multivariable linear regression models describing health outcome measures	74
Table 4.14 Injury coefficients from exploratory multivariable linear regression models describing fitness outcome measures	76
Table 4.15 Injury coefficients from exploratory multivariable linear regression models describing SEBT outcome measures.....	80

Table 4.16 Summary of confounders [✓] for exploratory analyses	82

List of Figures and Illustrations

Figure 3.1 Flow of study recruitment for 2014/2015 cohort	30
Figure 3.2 Flow of study recruitment for 2008/2009 cohort	31
Figure 4.1 Bland-Altman agreement between VO_2max estimated by PACER laps in PACER equation and PACER speed in Léger equation	52
Figure 4.2 Bland-Altman agreement between VO_2max estimated by Léger laps in PACER equation and Léger speed in Léger equation	53

List of Symbols, Abbreviations and Nomenclature

Symbol	Definition
S&R	Sport and recreation
PA	Physical activity
BMI	Body mass index
VO ₂ max	Maximal oxygen uptake
SEBT	Star Excursion Balance Test
MeSH	Medical Subject Headings
tw	Text words
ACL	Anterior Cruciate Ligament
SD	Standard deviation
IQR	Inter-quartile range
FINA	Fédération Internationale de Natation
KOOS	Knee Injury Osteoarthritis Outcome Score
IKDC	International Knee Documentation Committee
KOS-ALDS	Knee Outcome Survey- Activities of Daily Living Score
GRS	Global Rating of Perceived Function
RCT	Randomized controlled trial
PE	Physical education
PACER	Progressive Aerobic Cardiovascular Endurance Run
ECDB	Eyes closed dynamic balance
SIPRC	Sport Injury Prevention Research Centre
CSEP	Canadian Society for Exercise Physiology
CEP	Certified Exercise Physiologist
REDCap	Research electronic data capture

Chapter One: **INTRODUCTION**

1.1 Problem Statement

Sport and recreational (S&R) injuries are prevalent in the youth population, accounting for two of every three injuries sustained in 12-19 year olds.^{1,2} These injuries may result in time loss from physical activity participation and impact one's willingness to return to sport,³ and also pose a substantial economic burden.^{1,4,5} The high sport participation rates, as evidenced by the 75-94% of children and youth who reported participating in sport in the previous year, parallel the high prevalence of S&R injuries.⁶⁻⁸ Despite these favourable physical activity (PA) participation trends, there has been a decline in physical fitness levels in children and youth over the past few decades.^{9,10} This likely contributes to the increase in overweight and obesity over the same time period; however, this trend has been slowly declining in the past decade, while physical fitness levels are still decreasing.¹⁰ Children and youth who discontinue PA participation after sustaining an injury may be at greater risk of attributing an unhealthy body composition and low physical fitness levels.^{11,12} Obesity and low physical fitness have been associated with metabolic disorders in adulthood; however, the development of these negative health consequences has been identified at earlier ages.¹³

It is important to examine the influence of previous S&R injury on health and physical fitness outcomes to distinguish which parameters are most affected. This fundamental understanding is important for improving long-term health outcomes and decreasing the high rates of unhealthy body composition and low physical fitness that may arise as a result of injury in the youth population.

1.2 Research Purpose

The purpose of this study was to investigate if there was an association between self-reported one-year history of S&R injury and each of the following: body composition, cardiorespiratory fitness, musculoskeletal strength, and dynamic balance in junior high school students.

1.3 Background

1.3.1 Sport and Recreational Injury in Adolescents

Sport and recreational activities account for two-thirds of all injuries in 12-19 year olds.^{1,2} Acute sport injury can result in pain, disability, or dysfunction in both the short term and long term.¹⁴ For example, knee injury sustained in youth increases the risk of developing early onset post-traumatic osteoarthritis that can negatively impact quality of life, physical function during sport and recreational activities, and increase pain and symptoms.^{15,16} The most common injury types in the youth population are sprains and strains.^{1,3,8,14,17} Lower extremity injuries, specifically ankle and knee injuries, are prevalent in this population and account for up to 70% of all time loss injuries in youth.^{1,6,8,17-19} As a result, many sport injury prevention programs have been designed to address these injury patterns.²⁰⁻²⁸ Preventing injuries can help ensure that children and adolescents are able to participate in physical activity and sport, thereby preventing comorbidities associated with sedentary lifestyle that may arise from sustaining an injury and avoiding the associated healthcare costs that contribute to the economic burden associated with injury.³

1.3.2 Sport Participation

Youth sport participation in Canada is high, with 75% of Canadian youth and 93% of junior high school students in Calgary reporting sport participation at some point over the previous year.^{6,7} Fifty percent of children and adolescents participate in sport 2-3 times per week, while 34% participate at least four times per week.²⁹ Contrary to popular belief, research has found that the daily recommended 60-minutes of moderate-to-vigorous PA is not accumulated in a single organized sport session.³⁰⁻³² This indicates that additional sessions of PA at a moderate-vigorous intensity are necessary to obtain health benefits.³¹

1.3.3 Health and Physical Fitness of Canadian adolescents

The obesity epidemic is a concern in today's society, as a growing number of individuals of all ages are experiencing unhealthy weight gain that is affecting their physical, emotional, and social well-being.^{11,33} Children and youth in particular are increasingly exhibiting unhealthy body composition, with close to one-third (31.5%) of those 5-17 years of age classified as overweight or obese.³⁴ Evidence to support weight maintenance and prevention of chronic diseases through PA participation is well represented in the literature.^{10,35-37}

The Active Healthy Kids Canada Report Card on Physical Activity for Children and Youth reported that most jurisdictions in Canada are making PA a public health priority.²⁹ As such, 83% of Canadian schools have mandated daily recess, 95% of students have access to a gymnasium, and 91% have access to an outdoor playing field. Despite the accessibility of venues that promote PA, physical fitness levels of Canadian children and youth are lower compared to the same population in the 1970's and 1980's, particularly in musculoskeletal fitness and flexibility.^{33,34} Body composition, including body mass index (BMI), waist circumference, and

sum of five skinfolds, is also higher.³³ This may be explained by the sedentary lifestyles of today's children and youth, as they are spending 7.6 to 9.3 hours per day being sedentary.²⁹

Alongside the high rates of sport participation in Canadian children and youth, this population is also exhibiting unhealthy body composition, low physical fitness levels, and a high injury risk. It is important to investigate the association between injury history and body composition and physical fitness outcomes in youth, while accounting for sport participation.

1.4 Research Question and Specific Objectives

1.4.1 Primary Objectives

- 1) To determine if sport and recreational injury sustained within the previous 12 months is associated with body composition in 11-15 year old junior high school students, as determined by BMI z-scores and its classification as healthy/unhealthy.
- 2) To determine if sport and recreational injury sustained within the previous 12 months is associated with body composition in 11-15 year old junior high school students, as determined by waist circumference percentiles and classification as overweight/obese.
- 3) To determine if sport and recreational injury sustained within the previous 12 months is associated with lower body musculoskeletal fitness in 11-15 year old junior high school students, as determined by vertical jump height.
- 4) To determine if sport and recreational injury sustained within the previous 12 months is associated with cardiorespiratory fitness in 11-15 year old junior high school students, as determined by predicted relative VO_2max ('predicted VO_2max ') derived from 20-m shuttle run scores.

- 5) To determine if sport and recreational injury sustained within the previous 12 months is associated with dynamic balance in 11-15 year old junior high school students, as assessed by unipedal eyes closed dynamic balance on a foam pad.

1.4.2 Secondary Objective

- 1) To determine if sport and recreational injury sustained within the previous 12 months is associated with dynamic balance in 11-15 year old junior high school students, as assessed by the Star Excursion Balance Test (SEBT) normalized reach distances.

1.4.3 Exploratory Objectives

1. To determine if the number of sport and recreational injuries, time since the most recent injury, and severity of the most recent injury sustained within the previous 12 months is associated with body composition as assessed by BMI z-scores and BMI classification of overweight/obesity in 11-15 year old junior high school students.
2. To determine if the number of sport and recreational injuries, time since the most recent injury, and severity of the most recent injury sustained within the previous 12 months is associated with body composition as assessed by waist circumference and waist circumference classification of overweight and obesity in 11-15 year old junior high school students.
3. To determine if the number of sport and recreational injuries, time since the most recent injury, and severity of the most recent injury sustained within the previous 12 months is associated with cardiorespiratory fitness, as assessed by VO₂max scores derived from the 20-m shuttle run test.

4. To determine if the number of sport and recreational injuries, time since the most recent injury, and severity of the most recent injury sustained within the previous 12 months is associated with lower body musculoskeletal strength as assessed by vertical jump height.
5. To determine if the number of sport and recreational injuries, time since the most recent injury, and severity of the most recent injury sustained within the previous 12 months is associated with dynamic balance in 11-15 year old adolescent youth, as assessed by the unipedal eyes closed dynamic balance on the foam pad and by Star Excursion Balance Test (SEBT) reach distances.

1.5 Research Rationale

Sport participation rates are high in youth,⁶ and so is the risk of S&R injury.² Prospective and cross-sectional studies have focused on health and physical fitness parameters as risk factors for injury; however, the relationship between previous injury and health and physical fitness outcome measurements has not been examined. Returning to full PA participation post-injury is necessary to continue to obtain health benefits and maintain a healthy lifestyle from adolescence into adulthood. The results from this study can contribute to the existing literature on the relationship between S&R injury and health and physical fitness, and provide a different perspective regarding the health and physical fitness of adolescents following a S&R injury.

1.6 Summary of Thesis Format

This thesis contains six chapters, including an introduction, literature review, methods, results, discussion, and conclusion. Chapter one introduces the thesis and includes a problem statement, research purpose, background information, research question and specific objectives, research rationale, and a summary of the thesis format. The background includes information on

S&R injury, sport participation, and health and physical fitness in children and youth. Chapter two contains a review of the literature, which describes the search strategy, and a discussion and critique of the existing literature on previous injury and the health, performance, and physical fitness outcomes. Chapter three describes the methodology, including the study design, study population with inclusion and exclusion criteria, procedures, statistical methods, and ethical considerations. Results that address the primary, secondary, and exploratory objectives are reported in chapter four. Chapter five discusses the results and reports the strengths and limitations of the study. Chapter six concludes the thesis and includes implications for future research.

Chapter Two: **Literature Review**

2.1 Introduction

There are numerous studies that examine health and physical fitness parameters as potential risk factors for injury; however, literature discussing the influence of previous injury on health and physical fitness outcomes is scarce. Studies that do exist include elite athletes as the population of interest, and focus on a range of different outcomes such as balance and stability, sport-specific performance, return to sport or activity, and health and functional status. There are only a few studies reporting this relationship in children and adolescents.³⁸⁻⁴⁰ The objective of this literature review is therefore to examine the existing research evaluating the association between injury and body composition, cardiorespiratory fitness, lower body musculoskeletal strength, and dynamic balance. A critical appraisal of the literature is included to provide an evaluation of the existing body of knowledge in this area.

2.2 Methods

2.2.1 Data Sources

Four databases were searched for relevant articles in September 2015, including Medline(OVID), PubMed, SPORTDiscus, and Google Scholar. Searches were sorted by relevance and only original research was included. Reference lists of the selected articles were also searched to capture any relevant articles specific to the primary focus of the current study that may have been missed in the database search.

2.2.1.1 Search Terms

Table 2.1 Medical subject headings and text words used for article extraction

Medical Subject Headings (MeSH) *also used as text words in each search	Text words (tw)
1. Athletic Injuries	11. Injury
2. Wounds and Injuries	12. Sport injury
3. Physical Fitness	13. Physical Activity Injury
4. Outcome	14. Performance
5. Consequence	15. Youth
6. Health	
7. Health Outcome	
8. Athletic Performance	
9. Adolescent	
10. Child	

A. Injury: 1 OR 2 OR 11 OR 12 OR 13

B. Outcome: 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 14

C. Youth: 9 OR 10 OR 15

D. Injury outcomes in youth: A AND B AND C

2.2.1.2 Search Strategy

Only the titles of the first 300 articles listed in each database, sorted by relevance, were viewed. If the title indicated that the study examined an association between previous injury and

any outcome related to health, then the abstract was examined to determine if the study would be appropriate to include in the literature review.

2.2.2 Study Selection Criteria

Inclusion Criteria:

1. Peer-reviewed article
2. English language
3. Original research design

Exclusion Criteria:

1. Language other than English
2. Non-original research, such as reviews
3. Studies that examined injury as an outcome

Following the search strategy and the inclusion and exclusion criteria, n=15 articles were deemed to be relevant to the objectives of this literature review. Table 2.2 summarizes the selected studies, including authors, study population, study design, exposure, outcome, and a results summary. Articles are presented within sections by outcome. Any articles that investigated risk factors for injury were excluded from the literature review, since the study design did not focus on the outcomes of interest for this particular study.

Table 2.2 Summary of literature review results

Authors	Study Population	Study Design	Exposure	Outcome(s)	Results
Whittaker et al. (2015)	100 participants who participated in sport during youth	Case-control	Knee injury sustained while playing youth sports	SEBT, triple single leg hop, unipedal dynamic balance, lower limb strength, predicted VO ₂ max, BMI	Injured group performed significantly lower on the single leg hop test compared to the uninjured group (mean within pair difference= -30.9%, 95% CI -54.3, -7.6). Injured participants were 3.75 (95% CI 11.24, 11.3) times more likely to be overweight or obese. KOOS scores were significantly lower for the injured group in all 5 subscales. No differences in VO ₂ max, leg strength, unipedal dynamic balance, or SEBT were observed between injury groups.
Logerstedt et al. (2012)	83 female athletes	Prospective cohort	Previous ACL injury	Limb symmetry from single and triple hop performance	Single and triple hop limb symmetry were less than 90% at baseline (87.2, 95% CI 84.4, 90.0 and 87.1, 95% CI 84.7, 89.4, respectively), but improved to greater than 90% by six months post-surgery. Limb symmetry calculated from the six-metre timed hop test was greater than 90% (91.1, 95% CI 89.1, 93.1) at baseline.
Delahunt et al. (2013)	31 female athletes	Case-control	Previous ACL reconstruction	SEBT reach distance	Control participants demonstrated significantly higher reach distances in the posteromedial ($p<0.005$) and posterolateral ($p<0.005$) directions compared to the injured group. KOOS scores were significantly lower in the injured group for all 4 subscales.

de la Motte et al. (2015)	40 recreationally active adults	Case-control	History of chronic ankle instability	SEBT reach distance	No statistically significant differences between injury groups in any of the three SEBT reach directions.
Brown & Mynarck (2007)	40 recreationally active adults	Case-control	History of chronic ankle instability	Time to stabilization following perturbation	Time to stabilization was significantly longer in the injured compared to the control group in the anterior-posterior direction (0.78 ± 0.12 versus 0.71 ± 0.09 , $p=0.04$).
Akbari et al. (2006)	30 male athletes	Cross-sectional	History of chronic ankle instability	SEBT, functional reach test, sway index	Mean reach distance on the SEBT was lower when balancing on the injured limb compared to the uninjured limb (84.97, SD 10.26 cm versus 86.80, SD 9.34 cm, $p=0.025$). Functional reach test distances were lower in injured compared to uninjured limbs (30.39, SD 3.93 cm versus 34.79, SD 7.22 cm, $p=0.001$). Sway index was significantly greater for eyes open unipedal dynamic balance on the injured limb compared to the uninjured limb (2.42, SD 0.93 versus 1.84, SD 0.46, $p=0.001$). No differences in sway index were observed for the unipedal eyes closed test.
Huang et al. (2010)	30 youth baseball players	Case-control	History of medial elbow pain	Throwing kinematics and ball speed	Injured participants threw a significantly faster mean ball speed compared to their uninjured counterparts (24.8, SD 2.7 vs 23.0, SD 2.7 m/s $p=0.006$). Elbow flexion angle at maximal shoulder external rotation was significantly lower in the injured compared to uninjured group (91.2, SD 17.0 and 101.3, SD 10.4 respectively, $p=0.004$).

Marshall et al. (2015)	33 Major League Baseball pitchers	Case-control	Previous revision ulnar collateral ligament surgery	Statistical performance, return to play, career longevity	84.8% of injured players returned to pitch in the major or minor leagues, 65.5% returned to pitch in the major league. In the injured group, statistically significant declines in pitching performance post-surgery compared to pre-injury were observed, including innings pitched (67.18 versus 39.10, $p<0.01$), walks per nine innings (4.02 versus 4.79, $p<0.05$), and both number wins (3.61, SD 0.46 versus 1.89, SD 0.55, $p<0.01$) and losses (4.00, SD 0.50 versus 2.27, SD 0.56, $p<0.01$). Walks per nine innings was significantly lower for the injured group (4.75, SD 0.31 versus 3.49, SD 0.25, $p=0.001$).
Mountjoy et al. (2015)	1,116 elite swimmers	Prospective cohort	Physical complaint sustained 4 weeks prior to FINA	Swimming performance	Of the 1,116 athletes who completed the questionnaire, 33% (n=368) reported a physical complaint during this time period. Of these athletes, only 17% of them (n=57) reported that their performance had not been affected as a result of their injury.
Schmale et al. (2013)	29 skeletally immature participants	Cross-sectional	Transphyseal ACL reconstruction	Return to physical activity	41% of patients were able to maintain the same level activity post-surgery as they did before their injury. There was a significant decrease in Tegner activity scores when comparing pre-injury to follow-up after surgery (8 vs 7, $p=0.0026$).

Van Kleunen et al. (2012)	17 overhead throwing athletes	Cross-sectional	Surgical repair of SLAP tendon and infraspinatus tendon	Return to physical activity	35% were able to return to a similar level of play. 35% were not able to return to play, 29% were able to return but reported arm trouble, and 35% were able to play with no arm trouble.
Werner et al. (2014)	18 collegiate football athletes	Cross-sectional	Underwent suture anchor repair for UCL tear	Return to physical activity	All athletes were able to return to the same level of play as before their injury. Low QuickDASH scores were reported for all positions: 0 (95% CI 0.0-0.0) for skill players and 1.0 (0.0, 1.9) for non-skill players.
Irion et al. (2014)	13 elite athletes	Cross-sectional	Underwent surgery for chronic external compartment syndrome	Return to physical activity	All athletes returned to the same level of play, two could not maintain this level. Median time for return to play was 8.25 weeks (IQR 11.5).
Wilson et al. (2014)	2856 injured adults	Cross-sectional	Injuries reported to an insurance board	Health and function	39% reported that their health was worse after their injury compared to the previous year, 55% reported lower function in daily life and leisure activities.
Myer et al. (2014)	352 female youth soccer and basketball players	Prospective longitudinal	Knee injury	BMI	Injured group displayed significantly greater increases in BMI compared to uninjured group (mean difference=0.057, 95% CI 0.005 to 0.11, $p=0.03$ and 0.83, 95% CI 0.21 to 1.45, $p=0.009$, respectively).

2.2.3 Previous injury and balance outcomes

The literature search yielded six articles that examined the association between previous injury and balance in athletic and recreationally active adult populations. Whittaker et al. (2015)¹⁶ compared outcomes between 50 participants who had sustained a knee injury 3 to 10 years previously during youth sport with 50 healthy controls matched on age, sex, and sport. Balance measurements included unipedal dynamic balance, star excursion balance test (SEBT), and triple single leg hop. The injured group performed significantly lower on the single leg hop test (expressed as a percentage of leg length distance) compared to the uninjured group (mean pair difference= -30.9%, 95% CI -54.3, -7.6). No significant differences in performance on the unipedal dynamic balance or the SEBT were observed, although scores for injured participants were lower for both tests.

Logerstedt, Lynch, Axe, & Snyder-Mackler (2012)⁴¹ prospectively examined limb asymmetries in female athletes (aged 15-53) who had sustained an anterior cruciate ligament (ACL) injury. A variety of hop tests were assessed prospectively; baseline, prior to surgery, 6-months post-surgery, and 12-months post-surgery. Athletes also participated in a rehabilitation program before and after surgery. Hop performance on the injured limb was expressed as a percentage of hop performance on the uninjured limb. Single and triple hop limb symmetry was less than 90% based on results from the single and triple hop tests [87.2 (95% CI 84.4, 90.0) and 87.1 (95% CI 84.7, 89.4)], but improved to greater than 90% by six months post-surgery. Limb symmetry calculated from the six-metre timed hop test was greater than 90% (91.1, 95% CI 89.1, 93.1) at baseline. As hypothesized, limb asymmetries in functional balance tests assessing hop distance were present in female athletes who had sustained an ACL injury.⁴¹

Delahunt et al. (2013)⁴² also examined female athletes (mean age 20.6, SD 1.14 years) who underwent ACL reconstruction. Fourteen previously injured athletes were compared to 17 uninjured controls on SEBT reach distances in the anterior, posteromedial and posterolateral directions. At a 0.016 significant level (adjusted for the three reach directions; 0.05/3), independent t-tests revealed that control participants demonstrated significantly higher reach distances in the posteromedial ($p<0.005$) and posterolateral ($p<0.005$) directions compared to the injured group. This demonstrates a deficit in dynamic postural stability in ACL-reconstructed athletes.

Dynamic balance deficits have also been demonstrated in participants with chronic ankle instability. de la Motte et al. (2015)⁴³ compared performance on the SEBT between 20 recreationally active adults with history of chronic ankle instability to 20 controls matched on sex, height, weight, and dominant limb. Reach distances were measured in the anteromedial, medial, and posteromedial directions. Contrary to findings from Delahunt et al. (2013)⁴², there were no statistically significant differences between groups in any of the three reach directions on the SEBT based on independent t-tests. However, authors from both studies selected a different combination of reach directions.

Brown & Mynark (2007)⁴⁴ focused on a similar population of 20 recreationally active athletes with chronic ankle instability who were matched with 20 controls with no history of ankle instability. Using force plate measurements, researchers examined participant time to stabilization after receiving an electrical stimulation perturbation while attempting to maintain a double leg stance. In the anterior-posterior direction, independent t-tests indicated that the time to stabilization was significantly longer in the ankle injury group compared to the control group (0.78, SD 0.12 versus 0.71, SD 0.09, $p=0.04$) at a 0.05 significance level. No statistically

significant differences were reported for any of the other force plate measures, including in time to stabilization following perturbation in the medial-lateral direction.⁴⁴

Finally, Akbari et al. (2006)⁴⁵ assessed balance ability using the SEBT and functional reach test for unilateral stance in 30 right-side dominant male athletes (mean age 22.8, SD 4.8 years). The authors compared bilateral differences in the balance measures for the participants. For the analysis of each assessment, paired t-tests were used to assess means for each limb. Mean reach distance on the SEBT was significantly lower when balancing on the injured limb compared to the uninjured limb (84.97, SD 10.26 cm versus 86.80, SD 9.34 cm, $p=0.025$). It should be noted that the five reach directions used were not specified, and authors did not state that they normalized reach distance to leg length. Functional reach test distances were also significantly lower in injured compared to uninjured limbs (30.39, SD 3.93 cm versus 34.79, SD 7.22 cm, $p=0.001$). Sway index, measured using a force plate, was significantly greater for eyes open unipedal dynamic balance on the injured limb compared to the uninjured limb (2.42, SD 0.93 versus 1.84, SD 0.46, $p=0.001$), but no differences in sway index were observed for the unipedal eyes closed test. Paired t-tests were used to assess means for each limb.⁴⁵ Although results emerging from the above cross-sectional study are important, the methodology was poorly written, as it did not describe balance protocols in detail.

All of the studies that examined the influence of previous injury on balance outcomes included adult populations. Whittaker et al. (2015) selected participants who were injured while playing a sport during their youth; however, the mean age at the time of data collection was 22 years, and assessments were completed 3-10 years after injury. None of the studies objectively measured balance ability pre-injury, and instead made comparisons to either the uninjured limb^{41,45} or a group of uninjured participants.^{16,42-44} All studies collected injury data

retrospectively and objective measures and questionnaires were completed at one time point, with the exception of Logerstedt et al. (2012),⁴¹ who collected data at five time points prospectively. Some balance deficits do exist in injured participants as demonstrated by lower performance on the single leg hop,¹⁶ single and triple leg hop symmetry,⁴¹ SEBT reach distance,^{42,45} and time to stabilization in the anterior-posterior direction following a perturbation.⁴⁴ There were limitations in the study design in both the de la Motte et al. (2015)⁴³ and Brown & Mynark (2007) studies.⁴⁴ Analyses in both studies included independent t-tests, when paired t-tests should have been used due to the matched design. Results from these studies should be interpreted with caution.

2.2.4 Previous injury and performance

Three studies examined the influence of previous injury on sport-specific performance. One prospective cohort study examined performance outcomes of adult swimmers who had sustained an injury,⁴⁶ and two case-control studies were conducted on baseball players;^{38,47} one on youth and one on elite athletes. Huang, Wu, Learman, & Tsai (2010)³⁸ compared throwing kinematics between 15 youth baseball players who a history of medial elbow pain within the past year and their uninjured age-, height-, and weight-matched controls. Using electromagnetic motion analysis, authors used paired t-tests to compare differences in a variety of throwing kinematic measures between groups. At a 0.05 significance level, injured participants were able to throw a ball significantly faster compared to their uninjured counterparts (mean ball speed 24.8, SD 2.7 vs 23.0, SD 2.7 m/s respectively, $p=0.006$). The elbow flexion angle at maximal shoulder external rotation, which likely contributes to ball speed, was also significantly lower in the injured compared to uninjured group (91.2, SD 17.0 and 101.3, SD 10.4 respectively, $p=0.004$). The authors hypothesized that those players who had been injured were better pitchers

and thus were assigned more playing time, which may have contributed to their injury. However, no exposure data was collected.

Marshall et al. (2015)⁴⁷ also focused on baseball players; however, their population was limited to elite major league baseball players. Thirty-three pitchers who underwent revision ulnar collateral ligament reconstruction were matched with 33 uninjured controls on age and position (starting pitcher, closing pitcher, or relief pitcher). The equivalent of the year of surgery for the injured group was referred to as the “index year” for the control group. Internet websites reporting player statistics were used to collect performance outcome data for three years before and three years after the index year. For the surgery group, 84.8% of players returned to pitch in the major or minor leagues, whereas only 65.5% returned to pitch in the major league. A statistically significant difference in years of pitching after surgery was noted, with those who the surgery group pitching 4.0, SD 3.0 years versus 3.2, SD 2.6 years in the control group ($p<0.01$) in the major league. Similar results were found when looking at major and minor leagues, with the injured group pitching longer than the control group after the index year (5.0, SD 2.7 vs 4.1, SD 2.4 respectively, $p<0.05$). In the injured group, statistically significant declines in pitching performance post-surgery compared to pre-injury that were found included innings pitched (67.18 pre-surgery versus 39.10 post-surgery, $p<0.01$), walks per nine innings (4.02 pre-surgery versus 4.79 post-surgery, $p<0.05$), and both number wins (3.61, SD 0.46 pre-surgery versus 1.89, SD 0.55 post-surgery, $p<0.01$) and losses (4.00, SD 0.50 pre-surgery versus 2.27, SD 0.56 post-surgery, $p<0.01$). These findings are indicative of decreased pitching workload and shorter pitching career. Out of the 12 performance measures that were observed, only ‘walks per nine innings’ was significantly different between groups, with the injured group exhibiting better means compared to the control group (4.75, SD 0.31 versus 3.49, SD 0.25, $p=0<0.01$). Although

performance was maintained in most categories, this is likely explained by the decreased playing time exhibited by the injury group.

A prospective cohort study conducted by Mountjoy et al. (2015)⁴⁶ examined injuries sustained by athletes competing in aquatic sports at the 2013 Fédération Internationale de Natation (FINA) world championships. One of the objectives was to consider the association between physical complaints sustained 4 weeks prior to the championships, and the performance during the championships. Both of these measures were collected using a self-report questionnaire on the 1,116 athletes who agreed to participate. Thirty-three percent (n=368) reported a physical complaint during this time period; 17% (n=57) of who reported that their performance had not been affected as a result of their injury.⁴⁸

Only Huang et al. (2010)³⁸ objectively measured sport-specific performance. Marshall et al. (2015)⁴⁷ relied solely on player statistics to compare performance outcomes, while swimmers in the study conducted by Mountjoy et al. (2015)⁴⁶ reported performance subjectively. None of these three studies directly collected exposure before or after injury. Results from Mountjoy et al. (2015)⁴⁶ were subject to survivor bias, as they only included athletes in the study who were competing in the FINA championships and may have missed athletes who were unable to compete due to an injury. Further, the recall period for this study was extremely narrow, and may not have captured all injuries that influenced performance. Although each study collected performance measures differently, all provided some indication that performance may be negatively affected post-injury.

2.2.5 Previous injury and return to physical activity

Only one of the studies that included a focus on return to sport or physical activity after sustaining an injury was specific to adolescents. Schmale et al. (2014)³⁹ examined return to

activity in 29 skeletally-immature participants who underwent a transphyseal ACL reconstruction. Patients completed a questionnaire that included information on injury details, satisfaction post-surgery, function, return to sports, and activity levels compared to pre-injury. Forty-one percent (12/29) of patients reported that they were able to maintain the same level activity post-surgery as they did before their injury, based on Tegner activity scores. The Tegner Activity Level Scale is a questionnaire that asks athletes to indicate the highest level of activity that they were able to participate in before their injury, and the highest level that they are currently able to participate in, on a scale of one to ten. There was a significant decrease in Tegner activity scores when comparing pre-injury to follow-up after surgery (8 vs 7, $p=0.0026$). They also reported no correlation, based on Spearman's rank order correlation, between function as assessed using a Lysholm score and return to sports based on Tegner activity scores (93 vs 90, $p=0.05$). This indicated that higher knee function was not necessarily indicative of return to sport. Out of the 17 patients who did not return to the same level of activity in their respective sport after surgery, only one attributed this decision to poor knee function. The majority simply expressed that they no longer had a desire to continue to compete at higher levels. The wide follow-up period in this study (mean 4 years, range 2-8 years) was advantageous to examine long-term outcomes, but its retrospective design also resulted in a long recall period, increasing self-reporting bias.

Findings regarding return to physical activity and level of play in young ACL-reconstructed patients were lower when compared to high school and collegiate level baseball athletes who underwent concomitant surgical repairs of the superior labrum anterior-posterior and infraspinatus tendon tears.⁴⁹ Of the 17 participants in this retrospective study that obtained information on playing status and return to play via a questionnaire (mean follow-up time 37.2

months, range 24-55 months), 35% reported that they were able to return to a similar or better level of play compared to before their injury. The variable reporting return to play post-surgery compared to pre-injury was dichotomized (returning to lower level of play versus returning to similar or higher level of play), thus limiting the variability of responses. Thirty-five percent of athletes also reported that they were unable to return to play due to arm trouble, while 29% reported that they had returned to play but were still experiencing arm trouble, and 35% reported that they were able to play with no arm trouble. Using a validated questionnaire to assess self-reported throwing function (Kerlan-Jobe Orthopaedic Clinic questionnaire), the majority of athletes reported scores that were categorized as being in the 'fair' or 'poor' category for overhead throwing function, while none scored in the 'excellent' category and only one scored in the 'good' category. The authors concluded that although overhead throwing is a complex motion and that a variety of factors may influence performance decreases, rotator cuff injuries might have an impact on the throwing kinematics and performance ability.

Contrary to the low return to play proportions in the previously mentioned studies, Werner et al. (2014)⁵⁰ reported that all 18 collegiate football athletes who underwent suture anchor repair surgery for their complete thumb ulnar collateral ligament tear returned to at least the same level of play, two years after sustaining their injury. This study was also retrospective in nature, and asked players to complete a questionnaire that included a 'QuickDASH' score, used to measure arm, shoulder, and hand outcomes. A low score on this scale indicates low disability and a high score indicates high disability. The participants were separated into skill and non-skill positions, with skill position participants using their hands to throw or catch the football. The mean number of weeks before full return to play was 7 weeks (range 4-12 weeks) for skill position athletes, and 4 weeks (range 2-8 weeks) for non-skill position athletes

($p=0.027$). The mean QuickDASH score for skill position athletes was 0 (95% CI 0.0-0.0) and for non-skill position athletes was 1 (95% CI 0.0-1.9), indicating high functioning shoulder, arm, and hand outcomes.

Similar results regarding maintenance of level of play after surgery were reported by Irion, Magnussen, Miller, & Kaeding (2014),⁵¹ who evaluated return to physical activity in elite athletes after undergoing surgical treatment for chronic external compartment syndrome. All 13 athletes included in the study were able to return to their previous level of activity, but two were unable to continue to maintain that level of activity. Using a retrospective chart review to collect data, the authors reported that the mean time for return to sport was 8.25 weeks (range 6-12 weeks). Participants were put on a rehabilitation program following their surgery.

Finally, Mountjoy et al. (2015)⁴⁶ found that 76% ($n=273$) of the 368 swimmers who reported a physical complaint prior to the competition were fully participating in training in the remaining four weeks leading up to the competition. The median number of days of limited sport participation in this cohort was 6 days (IQR=11.5).

Four of the five studies discussed in this section of the literature review focused on athlete return to play after undergoing a surgical procedure for the respective injury. The focus of the current study is not specific to athletes and is inclusive of all types of sport and recreational injuries that require medical attention or result in time loss from physical activity participation, regardless of whether or not they required surgery. Further, only one included younger participants, whereas the rest included collegiate, scholastic, or elite athletes. These studies are not generalizable to a larger population, which makes it difficult to extrapolate the results. Further, four of the five include small sample sizes,^{39,49-51} ranging from 13 to 29 participants. Only one specified a 'return to play' definition.⁵⁰ These studies indicate that full return to sport

participation after sustaining an injury is highly likely once the athlete has had time to recover, but some may be unable to maintain their previous level of sport. Findings may be different in a recreationally active population or in children and adolescents.

2.2.6 Previous injury and health status

Health outcomes have been examined in those who have sustained an injury. In addition to outcomes previously discussed, Whittaker et al. (2015)¹⁶ also collected Knee Injury and Osteoarthritis Outcomes Score (KOOS) from each participant, which is a tool that assesses sport activities and in daily life. Injured participants reported significantly lower outcomes on all five categories of the KOOS, which included pain, symptoms, function in daily living, sport and recreation, and quality of life. Delahunt et al. (2013)⁴² also examined KOOS scores between injury groups, and found that injured patients reported significantly lower scores on all four of the KOOS subscales (this study did not include the pain subscale), as well as significantly lower scores on the self-reported International Knee Documentation Committee (IKDC) subjective knee form. The IKDC is designed to subjectively measure symptoms, sport activity, and function.

In addition to hop testing discussed previously, Logerstedt et al. (2014)⁴¹ had participants complete the Knee Outcome Survey-Activities of Daily Living Scale (KOS-ADLS) as well as a Global Rating Scale of Perceived Function (GRS). The percentage of patients who achieved greater than 90% on their self-report questionnaires improved from 42.7% at baseline to 98.6% 6-months post-surgery on the KOS-ADLS, and from 24.4% to 84.7% on the GRS. This demonstrates that function and outcomes related to the site of injury are impaired after sustaining an injury but can improve after undergoing a rehabilitation program after surgery.

General health as well as physical and social functioning outcomes were reported in a prospective cohort conducted by Wilson et al. (2014),⁵² which included 2,856 participants aged 18-64 years who had previously sustained an injury. Interviews were conducted following injury (median follow-up time 3.2 months) to collect outcome data. Subjective health characteristics included proportion of participants who felt that their overall health was worse than 1 year before their injury (39%) and proportion of participants who reported moderate or extreme pain in the previous 30 days (49%). Fifty-five percent reported lower participation in leisure and daily life activities, and 42% reported high scores (≥ 10) on the World Health Organization (WHO) Disability Assessment Schedule II.

Subjective measures from the aforementioned studies indicate that function in daily life and physical activity as well as overall health may be impacted post-injury. Both outcomes were important to maintain overall well being.

2.2.7 Previous injury and body composition

Whittaker et al. (2015)¹⁶ also assessed BMI differences between previously and non-previously injured groups. They found that previously injured participants were 3.75 times (95% CI 1.24, 11.3) more likely to have a BMI that classified them as overweight or obese. Similar results were reported by Myer et al. (2014),⁴⁰ who utilized a prospective longitudinal design to compare changes in BMI z-score and percent body fat between female youth soccer and basketball players with and without knee injuries. Participants reported injuries sustained over the course of the following twelve months, and body composition measurements were taken at baseline and 12 months. The final analysis included 352 participants and demonstrated significant differences in annual change of mean BMI z-scores and percent body fat between injured and uninjured athletes, with the injured group displaying significantly greater increases

compared to their uninjured counterparts (mean difference=0.057, 95% CI 0.005 to 0.11, $p=0.03$ and 0.83, 95% CI 0.21 to 1.45, $p=0.009$, respectively). The greater increase in BMI z-score change by five units and the clinically relevant increase in change of percent body fat demonstrate that there is an association between injury and unfavourable body composition. This study adjusted for pubertal maturation in the analyses; however, there are a multitude of other factors that may have also contributed to this relationship. The relationship may have also differed had the authors included time since injury to follow-up, and if they had also measured BMI and percent body fat at follow-up in injured participants who were unable to return to sport due to their injury.

2.2.8 Previous injury and physical fitness outcomes

No studies from those that emerged in the literature search primarily focused on cardiorespiratory or musculoskeletal fitness outcomes; however, these outcomes were included as components within some of the studies that assessed balance and functional outcomes. Only one study assessed fitness in their comparison between previously injured and uninjured participants. In addition to body composition, balance, and functional outcomes, Whittaker et al. (2015)¹⁶ assessed participants' predicted VO₂max values measured from the 20-m shuttle run. Although the performance was lower in the injured group, the difference was not significant (mean matched-pair difference=-1.9, 95% CI -5.2, 1.4). Additionally, the strength side-to-side differential strength ratio for quadriceps, hamstring, hip abductors and hip adductors and the quadriceps/hamstring and abductor/adductor strength ratios were not significantly different between groups.

2.3 Conclusion

Several studies have examined the relationship between previous injury and balance, performance, and function; however, there is little research that focuses specifically on health and physical fitness outcomes. This review has demonstrated that injury may be negatively associated with balance, as postural and dynamic balance deficits have been demonstrated in some studies. Although the literature has demonstrated that return to play is not greatly affected in athletes, this may not be the case for youth populations. Those who have sustained an injury are more likely to have a higher BMI based on the two studies discussed in this review, however the one study that examined fitness measures between injured and uninjured cohorts reported no differences. The majority of the existing literature focuses on athletes, and results are not generalizable to other populations. There is a need for research on the influence of previous injury on health and physical fitness outcomes in the child and adolescent population, as the current body of knowledge is limited.

Chapter Three: **METHODS**

3.1 Study Design

A randomized controlled trial (RCT) was piloted in two junior high schools in 2008/2009 to evaluate the effectiveness of a neuromuscular training program implemented in physical education (PE) classes to reduce injury and improve healthy outcomes. The same RCT design was implemented in four additional schools in the 2014/2015 school year. Data on health and physical fitness measurements were taken at baseline and follow-up in all six schools. Participants also completed a questionnaire at baseline that included information on sport participation and sport and recreational (S&R) injury history over the previous year. Baseline data were combined from both study years to conduct this cross-sectional study, with S&R injury history as the exposure variable and health and physical fitness measurements as outcome variables.

3.2 Study Population

The study population included grades 7, 8, and 9 students aged 11-16 years from junior high schools in Calgary. Forty-one of the 51 junior high schools from the Calgary Board of Education (excluding the two schools that were included in the 2008/2009 cohort) met the inclusion and exclusion criteria. All 20 schools in the western quadrants of Calgary and nine of 21 schools in the eastern quadrants of Calgary were approached for recruitment for the 2014/2015 cohort. Schools within each half of the city were randomly ordered and approached by the research coordinator in this order. The research coordinator first met with the principal of the school to discuss the study. If the principal agreed to allow the school to participate then the

research coordinator would return for a second visit to discuss the study with the teachers, who decided if they wanted to implement the warm-up program in their PE classes as part of the study. Twenty schools were approached in the west; 16 declined, two did not respond, and two agreed to participate. Nine schools were approached in the east; six declined, one did not respond, and two agreed to participate. Study recruitment is summarized in Figures 3.1 and 3.2.

Inclusion criteria for schools

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

Inclusion criteria for subjects

1. Students fully participating in the PE curriculum at baseline.
2. Students who return completed assent and parental consent forms (See Appendix B).
3. Students who return a completed PAR-Q+ (See Appendix C).

Exclusion criteria for schools

1. Schools that are culturally distinct (e.g., aboriginal perspective teaching).
2. Single-sex schools (i.e., boys' or girls' schools).
3. Schools that cater to students with special needs (e.g., behavioural programs).
4. Schools with incomplete grades (i.e., do not have all three junior high grades 7, 8, and 9).
5. Schools located outside of a 30-km radius of the University of Calgary.

Figure 3.1 Flow of study recruitment for 2014/2015 cohort

Figure 3.2 Flow of study recruitment for 2008/2009 cohort

3.3 Procedures

3.3.1 Data Collection

Data for this cross-sectional study were collected from December through March of the 2014/2015 school year. An information package was sent home with each of the students in the participating classes at the four randomly selected schools that included consent and assent forms as well as a questionnaire that evaluated S&R injury history over the previous 12 months and weekly physical activity participation. Upon returning the completed informed consent and assent forms to the school, questionnaires were collected and baseline measurements were taken.

Measurements specific to this study included body mass index (BMI) calculated from height and weight measures to assess body composition, waist circumference to assess body composition, predicted maximal oxygen uptake ($\text{VO}_{2\text{max}}$) from the Progressive Aerobic Cardiovascular Endurance Run (PACER) 20-m shuttle run to assess cardiorespiratory fitness, vertical jump height to assess lower body musculoskeletal fitness, and the star excursion balance test (SEBT) and unipedal eyes closed dynamic balance (ECDB) test using an Airex balance pad to assess dynamic balance. Each school was visited on two separate days, with a third visit at some schools in order to finish collecting baseline data from all participants. On the first testing day, half the students from each class performed the 20-m shuttle run while the other half underwent testing for the body composition, dynamic balance, and the lower body musculoskeletal assessments. On the second testing day, students who had previously completed the 20-m shuttle run underwent testing for the remaining fitness and body composition assessments, and vice versa. This was done to ensure that fatigue from the 20-m shuttle run did not influence vertical jump or balance scores on the same day.

Protocols for the vertical jump test and body composition measurements were adapted from the procedures described by the Canadian Society for Exercise Physiology-Physical Activity Training for Health manual (2004) as described below. The protocol for the 20-m shuttle run was based on the Fitnessgram PACER test.⁵³ The protocols for the ECDB test and the SEBT using the Y-balance equipment were consistent with those used in other studies run by the Sport Injury Prevention Research (SIPRC) Centre.

Measurements specific to the 2008/2009 study year also included BMI calculated from height and weight, waist circumference, vertical jump, and the ECDB test. The same protocols were used in both cohorts. Predicted VO₂max calculated from the Léger version of the 20-m shuttle run was used to assess cardiorespiratory fitness. The questionnaire also evaluated S&R injury history over the previous 12 months and hours of sport participation.

3.3.2 Study Questionnaire

The questionnaires from both the 2008/2009 and 2014/2015 cohorts can be found in Appendix D. Both questionnaires collected demographic information including age, grade, date of birth, height, weight, and menses cycle for females. Additionally, the 2014/2015 questionnaire collected parental level of education.

For both cohorts, injury history included any injury that required medical attention or resulted in time loss from physical activity within the past 6 weeks as well as over the previous 12 months. Information included injury date, injury type, anatomical location, sport of occurrence, treatment description, and estimated time loss from sport. The questionnaire also addressed concussion history, including date, activity, time unconscious, memory loss, time loss before full return to sport, and if memory, dizziness, or headaches were persistent.

Questionnaires from both cohorts collected information on previous weekly sport participation and PE participation (frequency and intensity), while only the 2014/2015 questionnaire collected additional information on active transportation (modality and hours per week), intensity of physical activity during PE class, physical activity during school hours not including PE class, and leisure time activity and intensity which was adapted from the Godin Leisure-Time Exercise Questionnaire ⁵⁴.

3.3.3 Outcome measures

The outcomes in this study are body composition, cardiorespiratory fitness, musculoskeletal fitness, and dynamic balance. The primary outcomes include BMI, waist circumference, predicted VO₂max, vertical jump height, and ECDB times. The secondary objectives include SEBT normalized composite reach distance and bilateral reach distance differences.

3.3.3.1 Body Composition:

BMI is calculated from the following equation: $BMI = \text{weight (kg)} / \text{height(m)}^2$

Thus, both weight and height must be accurately measured to determine the calculated BMI.

Height Measurement: Height was measured against a measuring tape adhered vertically to the wall. The subjects were asked to stand erect, without socks or footwear, with their heels and back against the wall. Their feet were positioned together, arms rested at their sides while facing straight ahead. The research personnel set a flat headpiece on top of the subject's head, depressing the hair. Distance from the floor to the lower border of the headpiece was measured to the nearest 0.1 cm.

Weight Measurement: The subject stood on the Tanita BF-350 scale, which was positioned on a flat surface, without socks or footwear and wearing light clothing such as shorts and a t-shirt. Weight was recorded in kilograms to the nearest 0.1 kg.

Weight and height were then used to calculate BMI. BMI z-scores were calculated using Stata 13.0 'zanthro' package, which calculates BMI z-scores using Centers for Disease Control and Prevention growth reference data from the United States.⁵⁵ BMI was also dichotomized into normal weight and overweight/obese based on International Obesity Task Force (IOTF) cutoffs.⁵⁶ BMI was assessed as a continuous variable (z-scores) and also as a dichotomous variable (normal weight, overweight/obese).

Waist Circumference: Waist circumference was measured by a Canadian Society for Exercise Physiology (CSEP) Certified Personal Trainer using anthropometric measuring tape.⁵⁷ The subject was asked to stand erect with their arms crossed across their chest. The researcher held the measuring tape between the thumb and index fingers. The tape was positioned horizontally, mid-way between the top of the iliac crest and the bottom of the ribcage. The measurement was taken at the end of a normal expiration, using a cross-handed technique to bring the zero line of the tape in line with the measuring line of the tape. Measurements were to the nearest 0.1 cm. Waist circumference was assessed as a continuous variable in cm and also as a dichotomous variable based on the 90th percentile of normative reference data from the 1981 Canadian Fitness Survey.⁵⁸ This cut-off was suggested by the International Diabetes Federation consensus group,⁵⁹ which categorizes those who are in the 90th percentile or higher as overweight/obese, and those who are below the cut-off are classified as healthy.

3.3.3.2 Cardiorespiratory fitness measurement: Predicted VO₂ max calculated from 20-m shuttle run results

The PACER 20-m shuttle run is a progressive, multistage test that indirectly predicts VO₂ max;⁵³ the maximal rate of oxygen consumption, measured in mL/kg/min. A higher predicted VO₂max indicates that an individual is able to consume more oxygen per kilogram of body weight, making them more efficient and thus demonstrating an increased aerobic capacity. The 20-m shuttle run test was administered to students in a group setting with approximately half the students performing the test at once, depending on the size of the PE class. Each student was given a sticker with a number that they placed on their shirt so that the researcher could easily identify when a student completed the test. Students lined up horizontally along the width of one end of the gym and on the cue of a beep from the soundtrack, began the test by running 20 metres to a marked line at the other end of the gym before the subsequent beep. The test is designed such that the necessary speed to complete each level of the test increases, beginning from a speed of 8.0 km/h. The speed increases by 1 km/h after the first stage (or first minute), and by 0.5km/h every stage (or minute) thereafter. Further, the number of laps within each stage increases. The test is completed when the subject is no longer able to follow the pace, and their score is recorded as their previously accomplished lap.

From the 2014/2015 cohort, each participant's predicted VO₂ max was calculated using the equation age and number of completed laps, and is used by the FitnessGram ($VO_{2max}=45.619 + [0.353 \times \text{PACER laps}] - 1.121 \times \text{Age}$). Predicted VO₂ max was assessed as a continuous variable.

A research coordinator and a CSEP-Certified Exercise Physiologist (CSEP-CEP) were present during the 20-m shuttle run tests. Both personnel ensured that participants were reaching the lines at each end of the marked distance, and recorded the last lap that the participants completed. After completing the test, participants were asked to perform an active recovery procedure by continuing walking at a light intensity to decrease heart rate back to resting levels. Participants did not participate in the 20-m shuttle run if they did not return a completed PAR-Q+, or who did complete a form but answered 'No' to at least one of the questions on the form and were not cleared by the CSEP-CEP.

The Léger 20-m shuttle run was used to assess cardiorespiratory fitness in the 2008/2009 cohort. Since this is the original shuttle run and all subsequent versions have been adapted from the Léger, it is designed in the same way and follows similar protocols, but starts from a speed of 8.5 km/h and in the first stage and increases by 1 km/h for each stage thereafter. The equation used takes into account running speed corresponding to the highest stage achieved and age ($VO_{2max}=31.025 + 3.238*\text{speed} - 3.248*\text{age} + 0.1536*\text{speed}*\text{age}$).⁶⁰ Predicted VO_{2max} values derived from each equation for the respective study year were assessed as a continuous variable.

3.3.3.3 Lower body musculoskeletal strength: Vertical Jump test

Vertical jump test is a measure of lower body musculoskeletal strength, representative of leg strength. The protocol used for the vertical jump test was adopted from the CSEP-Physical Activity Training for Health.⁶¹ The student was asked to stand perpendicular to the wall. A ruler or other measuring device was positioned on the wall alongside a posted sheet of large paper. The research personnel coloured the middle finger tip with a marker. The student was then asked to reach as high as possible with their fingers fully extended and palm facing the wall, ensuring

their feet remain flat on the floor. This point was marked on the wall, which was recorded as the standing height to the nearest 0.1 cm (measured from the top of the fingerprint mark). For the jump, the students were instructed to bring their arms downward and backward while bending their knees into a semi-squat position. After pausing in this position, they were asked to swing their arms forwards and upwards to gain momentum as they jumped as high as possible off both feet. They hit the paper at the peak height of their jump, again with their fingers fully extended and palm facing the wall. This was recorded as their jump height (measured from the top of their fingerprint mark). The standing height measurement was subtracted from the jump height measurement. The best of three jump heights was assessed as a continuous variable, in centimetres.

3.3.3.4 Dynamic Balance

Balance test protocols used were the same as those adopted by the SIPRC lab, which have been used in numerous studies in previous years and have demonstrated moderate to excellent reliability.^{62–65}

Star Excursion Balance Test:

The Y-balance test kit (functionalmovement.com, Danville, VA) was used for the SEBT. This consists of a central platform where the stance leg is placed, and three pipes are attached centrally and extend out in the anterior, posteromedial, and posterolateral directions. The posterior pipes are positioned 45 degrees apart from each other, and 135 degrees from the anterior pipe. Increments on each pipe are marked 0.5cm apart. A reaching block is attached to each of the pipes, and slides along the pipe when pushed by the participant.⁶⁶ Following a visual and verbal demonstration from the research personnel, the students were given one trial attempt

in each direction in order to become familiar with the testing procedures prior to the start of the test, where he/she completed one successful trial on each foot. Participants completed the test barefoot,⁶³ with one foot placed on the centre piece with their toes behind the red line. Once the student was able to balance with their hands on their hips, they reached out with their non-stance leg as far as possible while pushing the sliding piece with their toes, and held this maximal reach distance for 2-seconds in the anterior direction. They would then return their foot to the centre and rested their foot down momentarily to regain their balance. This procedure was repeated in the posterolateral and posteromedial directions. The trial was repeated if (adapted from Plisky et al., 2006):⁶⁷

- The non-stance leg touched down during a reach or before returning back to the center from each direction
- The non-stance leg moved outside the range of the red line
- The student did not rest for 2-seconds at their maximal reach distance
- The student removed their hands from the hips
- The student removed the stance foot from the center piece

The reach distance in each of the three directions for each leg was recorded to the nearest 0.5 cm. Participants were given one practice trial, and one test trial for each leg. Although studies have found that 4-6 practice trials and 3 test trials are valid as they account for the learning effect and for fatigue,^{63,67,68} only one practice trial and one test trial were administered due to severe time constraints during testing. Additionally, leg length of each participant was measured, and reach distance was normalized to leg length and expressed as a percentage.⁶⁴ Normalized reach

distances are expressed as composite scores and for each individual reach direction. These allow scores to be compared among individuals or groups.⁶⁸

Eyes closed dynamic balance test:

The student was given a 15-second practice session in order to familiarize themselves with the test, prior to the start of the 3 consecutive testing sessions on each foot. The student was asked to complete the test barefoot. They were instructed to step onto a foam pad with one foot while keeping their hands on their hips. The research assistant started the time as soon as the student closed their eyes, after they felt they could maintain a stable balance on their stance foot. The maximum trial time in seconds was recorded. If a student was not able to balance for two seconds, the trial was discarded and they were asked to try again. The research assistant stopped the time upon loss of balance, which included:

- One or both hands removed from the hips
- Eyes open
- Free leg touches down, or uses static leg for support
- Balance on the pad is kept but pad moves from original position, or the static leg raises from the pad

The students completed three test trials for each leg. Since the reliability of the eyes-closed dynamic balance test has been assessed in adolescents,⁶² it was used as the primary balance outcome for this study.

3.3.4 Exposure variables

The exposure variables in this study included S&R injury history and mean weekly hours of sport participation over the previous 12 months. These measures were assessed via a questionnaire administered to participants.

3.3.5 Previous Sport Participation

Mean weekly hours of sport participation over the previous 12 months was used as the sport participation variable to represent physical activity participation, as this information was available from the questionnaires distributed to both cohorts. The questionnaire included a list of a variety of different sports, and participants reported the number of hours per week and the number of weeks over the previous year that they participated in each sport. They were also able to include any sports that were not listed. Sport participation was estimated based on the sum of all self-reported participation hours in all sports for the previous year, divided by 52 weeks, to represent mean weekly hours of sport participation per year.

3.3.6 Injury History

A questionnaire that was administered to participants collected information on S&R injury history over the previous 12 months. This included additional information on body part of injury, severity, time since injury, and number of injuries. Injury was defined as any injury sustained from a sport or recreation activity within the previous 12 months that required medical attention or resulted in time loss from PA for at least one day. This definition included concussions. Previous injury was dichotomized (Injured/Uninjured) for the primary analysis. Time since injury was estimated as the number of days from the date of injury to the date that the

health and physical fitness measurements were taken. For the purpose of the exploratory multivariable linear regression analysis (described in Section 3.4), the time since injury for participants who reported not sustaining an injury was coded as 0 days. Severity of injury was included in the regression model as number of days before full return to PA participation within the last year. Injury severity was coded as 0 in the multivariable regression analyses for those who did not sustain any injury within the previous year, as well as for those who reported an injury but did not miss any days from PA participation.

3.4 Statistical Methods:

3.4.1 Descriptive Statistics

Data were analyzed using STATA 13.1 software. Sample sizes and rates of consent (%) were reported for each cohort, as well as for the combined data. Baseline data from all four schools in this cross-sectional study, as well as baseline data from the two schools used in the RCT, were combined and summarized with descriptive statistics. Data was assessed for symmetry/normality, and appropriate measures of central tendency were reported (means and 99% CI or medians and 99% CI for numerical or continuous data, and % and 99% CI for categorical data) for each of the outcome variables in addition to age, sex, and mean weekly hours of sport participation for each the previously injured and uninjured groups. The PA variables were reported as mean hours per week. Proportions were reported for each of the injury descriptors; injury type in descending order from most common, body part, and number of injuries

Independent t-tests determined the mean differences with 99% confidence intervals (or Bonett-Price median differences with 99% confidence intervals for data that did not follow a

normal distribution) between the injury groups for the outcome measures (BMI, waist circumference, predicted VO₂max, vertical jump height, ECDB, and SEBT). These tests served as the crude analyses for each outcome variable. Since there were 5 main objectives (BMI, waist circumference, predicted VO₂max, vertical jump height, ECDB), a significance level alpha of 0.01 was used for statistical tests, stemming from a Bonferroni correction ($\alpha/\text{number of tests} = 0.05/5 = 0.01$). The SEBT analyses were assessed as secondary outcomes, since this was the only outcome measurement that was not included in the 2008/2009 study year.

3.4.2 Bland-Altman Limits of Agreement

The Bland-Altman method was used to assess the agreement between the two equations used to predict VO₂max for each of the 20-m shuttle run versions. This method included plotting the mean difference between the two measures against the mean of the two measures for each individual. For participants from the 2014/2015 cohort, VO₂ max predicted from the PACER equation using PACER laps was compared to VO₂max predicted from the Léger equation using speed (as derived from number of laps collected from PACER). For participants from the 2008/2009 cohort, VO₂ max predicted from the Léger equation using Léger speed was compared to VO₂max predicted from the PACER equation using number of laps (as derived from speed collected from the Léger). The mean difference and the 95% limits of agreement were estimated using the units of measurement for predicted VO₂max (mL/kg/min). This provides an estimate of the range including 95% of the mean differences.

3.4.3 Multivariable Analyses

3.4.3.1 Primary and Secondary Objectives

Regression analyses were used to determine if an association existed between previous S&R injury (Yes/No) and each of the outcome variables (BMI, WC, vertical jump scores, predicted VO₂ max, balance times, and normalized reach percentages). BMI was assessed continuously (z-scores), and also as a dichotomous variable (normal weight and overweight/obese) based off IOTF cut points. Waist circumference (cm) was assessed continuously, and was also dichotomized into healthy and unhealthy using a cut point of the 90th percentile based on normative reference data from the 1981 Canadian Fitness Survey.⁵⁹ 20-m shuttle run scores were converted into predicted VO₂ max values and expressed as a continuous variable. Vertical jump height (cm) and dynamic balance times (seconds) were assessed as continuous variables. SEBT reach distances were normalized to leg length and expressed as a percentage for each direction and also as a composite score, as well as a bilateral limb distance (in cm) in each reach direction. These were also expressed as continuous variables.

Sample size estimates for each of the five main objectives were calculated at a 0.01 significance level. A sample size of 150 students is needed to detect an effect size of 3 in BMI z-scores, 40 students are needed to detect an effect size of 12 cm in waist circumference, 270 students for an effect size of 2 in shuttle run levels, 82 students for an effect size of 6 cm in the vertical jump, and 316 students for an effect size of 2 seconds in the eyes closed dynamic balance test. The sample size calculation accounted for clustering by class. See Appendix A for full sample size calculations to power this cross-sectional study.

Sport participation (mean hours/week), age group (dichotomized based on the mean of 13 years; 11-13 year-olds and 14-16 year-olds), and sex (female/male) were included as independent variables in each of the regression analyses. Linear regression models were used to assess continuous outcome variables (waist circumference, BMI, vertical jump height, predicted VO₂ max, balance time, SEBT normalized reach percentages, and SEBT bilateral reach distance differences) and logistic regression models were used to assess dichotomous outcome variables (BMI and waist circumference categories). A-priori statistical significance level for all analyses was set at 1% ($\alpha=0.01$). All covariates were treated as both potential modifiers and confounders in the regression analyses, and were assessed using a backwards elimination process. Odd ratios with 99% confidence intervals were reported from the final logistic regression models, and the estimated rate of change of means were reported for the final linear regression analyses. Data from both cohorts were included for all analyses, with the exception of the SEBT as it was not measured at baseline in the pilot study.

3.4.3.2 Exploratory Objectives

The exploratory analyses included time since injury, severity of injury, and number of injuries as exposure variables in each model. Number of injuries (0,1,2) was reported as a categorical variable, and included previously injured and uninjured individuals. Appropriate regressions were carried out based on categorical or continuous outcome variables as described above, with respective covariates. Time since injury was reported in days as a continuous variable, as was severity of injury (number of days from the date of injury to the date of the player's return to full participation in sport and recreational physical activity). Again, a-priori statistical significance level for all analyses was set at 1% ($\alpha=0.01$) to determine potential

modifiers. The models with body composition outcome variables (and waist circumference) assessed for modification by sex, while the remaining models for the physical fitness and balance outcome variables assessed for modification by sex and sport participation. Sport participation, age, and sex were assessed for confounding in every model. Odds ratios and 99% confidence intervals were reported from each of the final logistic regression models, and estimate rate of change of the means were reported from each of the final linear regression models.

3.5 Ethical considerations

Ethics approval was granted from both the Conjoint Health Research Ethics Board and from the Calgary Board of Education prior to recruiting schools. Written parental consent and participant assent were obtained from the students, and written consent was obtained from the teachers prior to collecting data. All data was stored in a hard-copy version in a locked filing cabinet in the SIPRC at the University of Calgary, as well as in a password-protected electronic format in REDCap (Research Electronic Data Capture) database to ensure participant confidentiality. All subjects received a unique study identification number linked to their data in order to protect personal identifiers such as names. Only the primary researchers, research assistants tasked with entering the data, and research coordinators have access to the data.

All research assistants helping with data collection obtained a City of Calgary Police Information Check, as required by the Calgary Board of Education to work in a school setting. During training the research assistants were briefed on the importance of privacy and confidentiality, which was adhered to during testing. Only participants who had answered ‘No’ to all questions on the PAR-Q+ form, or who had been cleared by a CSEP-CEP based on a subsequent completion of the Par-MEDX form participated in the 20-m shuttle run test. During

testing sessions, subject distress was controlled for by taking the waist circumference measurements privately, and by not sharing results. Testing was not completed on an individual if they did not feel comfortable with the measurement (i.e., waist circumference or weight).

Chapter Four: **RESULTS**

4.1 Study Participants

In total, 725 students consented to participate in the 2008/2009 study and 425 consented to participate in the 2014/2015 study. Data were missing from seven participants in the 2008/2009 study year and from 20 participants in the 2014/2015 study year because they did not complete any relevant measures at baseline. An additional 84 participants from the 2014/2015 cohort did not provide information on previous injury history. Participants with missing data were removed from the analysis. The final study population was composed of 1,039 students from grades 7, 8, and 9, from six junior high schools in Calgary.

The study sample included 584 (56.2%) females and 455 (43.8%) males. Ages ranged from 11 to 16 years, with a median age of 13 years. Three hundred ninety-five participants were in grade seven, 347 in grade eight, and 294 in grade nine. In total, 188 participants (18.1%) reported sustaining a sport or recreational (S&R) injury within the previous 12 months that resulted in either time loss from physical activity or required medical attention, and 851 (81.9%) reported no previous injury. Table 4.1 summarizes basic participant demographic information stratified by previous injury.

Table 4.1 Participant demographics by previous injury status

Characteristic		No previous injury	Previous injury
Sex (n, %)	Female	475 (55.8%)	109 (58.0%)
	Male	376 (44.2%)	79 (42.0%)
Grade (n, %)	7	340 (40.0%)	55 (29.6%)
	8	280 (32.9%)	67 (36.0%)
	9	230 (27.1%)	64 (34.4%)
		Mean (99% CI) or Median (99% CI)	
Age (years)		12.9 (12.8, 13.0)	13.1 (12.9, 13.2)
Height (cm)		160.3 (159.5, 161.1)	161.8 (160.1, 163.5)
Weight (kg)*		49.2 (48.0, 50.4)	52.0 (49.7, 54.3)
Sport participation (hrs/week)*		2.4 (2.1, 2.7)	4.2 (3.1, 5.4)

*Data is not normally-distributed; therefore, the measure of central tendency presented is the median (99% CI)

4.2 Previous Sport and Recreational Injury

One hundred eighty-eight participants reported that they sustained at least one injury in the previous year. Time since injury and injury severity were included in the exploratory multivariable linear regression analyses for the most recent injury. The mean time since injury, reported by 126 of the 188 injured participants, was 181.7 days (95% CI 153.1, 210.4). A total of 158 of the 188 participants who reported a previous injury also reported the number of days before full return to physical activity participation (injury severity). The mean number of days lost from physical activity as a result of the most recent injury was 11.9 (95% CI 7.7, 16.1). A total of 184 of the 188 participants who reported they had sustained a S&R injury in the previous year also provided information on injury frequency. One hundred seventy-four participants sustained one injury, and ten participants sustained two injuries. The remaining 851 participants who reported that they did not sustain an injury, or who reported an injury that was sustained greater than twelve months prior to the data collection dates.

4.2.1 Type of injury

Participants were also asked to report the body part that sustained an injury. A total of 174 participants provided details on the types of their most recent injury. The most common injury was a ligament sprain, followed by a muscle or tendon strain, then a fracture. “Other” injury types were those that were not detailed enough to classify into one of the categories, and included “medical condition”, “pain” and “passed out from a track and field event”. The types of injuries are reported in Table 4.2, listed in descending order of frequency.

Table 4.2 Self-reported injury by injury type

Type of Injury	Frequency (%)
Ligament sprain	73 (38.8)
Muscle strain/Tendonitis	30 (16.0)
Fracture	26 (13.8)
Concussion	19 (10.1)
Bruise/Contusion	10 (5.3)
Cut/Laceration	6 (3.2)
Inflammation	5 (2.7)
Other	3 (1.6)
Dislocation/Subluxation	2 (1.1)
Missing	14 (7.4)

4.2.2 Injured body part

Participants were also asked to report the body part that sustained the injury. One hundred seventy-eight (94.7%) of the 188 participants who reported sustaining an injury in the previous one year provided some detail on the anatomical location of the most recent injury. One participant reported two sites for the same injury, therefore a total of 179 injury locations were

reported. The most frequently injured body part was the ankle (18.5%), followed by the knee (16.4%). The anatomical locations of injury are reported in Table 4.3, listed in descending order of frequency.

Table 4.3 Self-reported injury by body part

Body part n=179	Frequency (%)
Ankle	35 (18.5)
Knee	31 (16.4)
Face/Head/Neck	27 (14.3)
Hand	18 (9.5)
Foot	16 (8.5)
Leg	13 (6.9)
Arm/Elbow	9 (4.8)
Wrist	9 (4.8)
Back	7 (3.7)
Shoulder complex	6 (3.2)
Groin/Hip	4 (2.1)
Trunk	4 (2.1)
Missing	10 (5.3)

4.3 Predicted VO₂max Agreement between 20-m shuttle run tests

The Bland-Altman method was used to estimate agreement between VO₂max predicted from the PACER equation and VO₂max predicted from the Léger equation for each version of the shuttle run. Mean differences and 95% limits of agreement are presented in Table 4-4. For both comparisons, the mean difference was close to 0 mL/kg/min, and the 95% limits of agreement included the null value of 0 mL/kg/min. Figures 4.1 and 4.2 display the agreement between VO₂max predicted by the PACER equation and VO₂max predicted by the Léger equation for each cohort. The y-axis represents the difference between the predicted VO₂max using each equation on one cohort, and the x-axis represents the mean predicted VO₂max from

all participants using the appropriate equations ([mean VO₂max predicted by PACER equation using PACER data + mean VO₂max predicted by Léger equation using Léger data]/2).

Table 4.4 Bland-Altman mean difference and 95% limits of agreement for VO₂max estimated by PACER and Léger 20-m shuttle runs

Comparison	Mean Difference (mL/kg/min)	95% Limits of Agreement (mL/kg/min)
VO ₂ max estimated by PACER test	0.467	-2.999 to 3.932
VO ₂ max estimated by Léger test	1.136	-2.574 to 4.847

Figure 4.1 Bland-Altman agreement between VO₂max estimated by PACER laps in PACER equation and PACER speed in Léger equation

Figure 4.2 Bland-Altman agreement between VO_2max estimated by Léger laps in PACER equation and Léger speed in Léger equation

Figure 4.1 demonstrates random scatter about the null value, but for a higher mean predicted VO_2max (beginning at approximately 60 mL/kg/min), the PACER equation estimates a higher VO_2max compared to the VO_2max estimated from the Léger equation in those who ran the PACER 20-m shuttle run. Figure 4.2 demonstrates that as the mean predicted VO_2max increases, the PACER equation increasingly estimates a higher VO_2max compared to the VO_2max estimated by the Léger equation for those who ran the Léger 20-m shuttle run.

4.4 Health and Physical Fitness Outcome Measures

4.4.1 Crude Analysis

4.4.1.1 Descriptive Statistics

Descriptive statistics were used to summarize outcome measures. The only outcome variables that deviated from normality were the ECDB measures, both of which were right-

skewed. Measures of central tendency (means for normally distributed outcome data and medians for non-normally distributed outcome data) were reported by injury status (injured/uninjured) for each outcome measure, accompanied by 99% confidence intervals (Tables 4.4-4.6). Data were further stratified by sex (female/male) and age group (11-13 years/14-16 years). Mean differences (injured-uninjured) and 99% confidence intervals calculated from independent t-tests were also reported for all normally distributed outcome variables between injured and uninjured participants, and Bonett-Price median differences (injured-uninjured) with 99% confidence intervals were reported for the non-normally distributed ECDB variables. These differences are reported in Tables 4.5-4.7.

Mean body mass index (BMI) z-scores were higher in participants that reported a previous S&R injury, compared to those reported no injury. These differences; however, were not statistically significant. This apparent difference was also observed when BMI was assessed dichotomously (healthy vs. overweight/obese), where there were a greater proportion of students classified as overweight or obese in the injured group compared to the uninjured group.

Mean waist circumference was also higher for injured participants when stratified by age group and sex, although differences within each strata were not statistically significant. There were also no statistically significant differences when reporting by waist circumference categorization (healthy, unhealthy). However, the proportion of participants classified as having an unhealthy waist circumference were higher in uninjured females and in 14-16 year old males compared to those who were injured. In contrast, injured 11-13 year old males demonstrated a higher proportion of unhealthy waist circumference compared to their uninjured counterparts.

None of the mean or median differences were statistically significant in any of the physical fitness or balance measures (predicted VO₂max, vertical jump, ECDB, or SEBT reach

components), however some trends were observed. Injured participants demonstrated better predicted VO_2max scores and vertical jump height compared to uninjured participants within all strata (Table 4.6). Injured participants also demonstrated better right and left foot balance times compared to uninjured participants, with the exception of left foot balance in 14-16 year-old males.

The SEBT was not conducted on participants in the 2008/2009 study year, thus the sample size for this outcome measure was smaller compared to the other measurements and was only assessed as a secondary objective in this study. Right and left foot composite normalized reach distances (%) were slightly better in the injured group within all strata, with the exception of 14-16 year old females. Larger bilateral reach distance differences were observed in injured 14-16 year old males for all reach directions, in both age groups of injured females for the anterior direction, and in 11-13 year old females in both the medial and lateral directions. Mean differences in 11-13 year old males were the same among injury groups for the lateral direction, while uninjured participants demonstrated larger differences in the remaining strata (uninjured 11-13 year old males for the anterior and medial directions, and uninjured 14-16 year old females in the lateral and medial directions). Again, there was no evidence of statistical significance in any of the SEBT measures (Table 4.7).

Table 4.5 Health outcome measures for injured and uninjured groups stratified by age and sex

Outcome measure	Age group (years)	Mean (99% CI) or % (99% CI)					
		Females			Males		
		Uninjured	Injured	Mean Difference	Uninjured	Injured	Mean Difference
BMI z-score	11-13	0.12 (-0.02, 0.27) n=355	0.37 (0.08, 0.67) n=68	0.25 (-0.10, 0.60)	0.36 (0.16, 0.56) n=248	0.79 (0.39, 1.17) n=49	0.43 (-0.05, 0.90)
	14-16	0.16 (-0.05, 0.37) n=107	0.26 (-0.19, 0.71) n=38	0.10 (-0.34, 0.53)	0.18 (-0.08, 0.45) n=117	0.40 (-0.17, 0.98) n=27	0.22 (-0.39, 0.83)
BMI category (% overweight/obese)	11-13	14.1 (9.3, 18.8) n=355	22.1 (9.1, 35.0) n=68	8.0 (-5.8, 18.8)	19.4 (12.9, 24.8) n=248	30.6 (13.7, 47.6) n=49	11.3 (-6.9, 29.4)
	14-16	14.0 (5.4, 22.7) n=107	15.4 (5.0, 30.3) n=39	1.4 (-15.8, 18.6)	14.5 (6.1, 22.9) n=117	25.9 (4.2, 47.6) n=27	11.4 (-11.9, 3.5)
Waist circumference (cm)	11-13	66.6 (65.6, 67.7) n=356	67.8 (65.5, 70.1) n=67	1.2 (-1.4, 3.8)	68.7 (67.1, 70.2) n=246	70.8 (67.1, 74.5) n=48	2.1 (-1.7, 5.9)
	14-16	69.5 (67.5, 71.4) n=108	71.1 (66.9, 75.4) n=38	1.7 (-2.4, 5.7)	72.1 (69.9, 74.2) n=118	72.7 (68.0, 77.4) n=27	0.7 (-4.2, 5.5)
Waist circumference category (% overweight/obese)	11-13	1.4 (0.0, 3.0) n=360	0.0 (0.0, 0.0) n=68	-1.4 (-3.0, 0.0)	2.0 (-2.8, 4.2) n=254	5.8 (-2.6, 14.1) n=52	3.8 (-12.4, 4.8)
	14-16	3.6 (-0.9, 8.2) n=111	2.5 (-3.9, 8.9) n=40	-1.1 (-8.9, 6.7)	3.3 (-0.8, 7.5) n=121	0.0 (0.0, 0.0) n=27	-3.3 (-7.5, 0.8)

Table 4.6 Fitness outcome measures for injured and uninjured groups stratified by age and sex

Outcome measure	Age group (years)	Mean (99% CI) or Median (99% CI)					
		Females			Males		
		Uninjured	Injured	Difference	Uninjured	Injured	Difference
Predicted VO ₂ max (mL/kg/min)	11-13	46.6 (46.0, 47.3) n=328	47.7 (46.2, 47.4) n=62	1.1 (-0.6, 2.8)	49.4 (48.5, 50.4) n=227	50.5 (48.5, 52.5) n=43	1.0 (-1.4, 3.4)
	14-16	45.0 (43.7, 46.2) n=100	45.5 (44.0, 46.2) n=31	0.5 (-2.1, 3.2)	51.3 (49.8, 52.7) n=106	52.4 (49.0, 55.9) n=21	1.2 (-2.4, 4.7)
Vertical jump height (cm)	11-13	29.9 (29.0, 30.8) n=337	31.1 (28.9, 33.3) n=64	1.2 (-1.1, 3.5)	34.1 (32.8, 35.5) n=238	34.5 (32.1, 37.0) n=52	0.4 (-2.7, 3.5)
	14-16	31.1 (29.5, 32.6) n=103	32.1 (28.4, 35.8) n=38	1.0 (-2.3, 4.4)	40.8 (38.8, 42.8) n=109	41.1 (36.1, 46.2) n=26	0.4 (-4.3, 5.0)
Right foot timed eyes closed dynamic balance (sec)*	11-13	3.5 (3.2, 3.9) n=311	3.9 (3.3, 4.5) n=60	0.4 (-0.4, 1.1)	4.0 (3.4, 4.6) n=205	4.5 (3.5, 5.5) n=41	0.5 (-0.7, 1.7)
	14-16	3.4 (2.7, 4.0) n=97	3.5 (2.1, 4.9) n=29	0.1 (-1.4, 1.7)	4.2 (3.5, 4.9) n=105	4.5 (3.0, 6.0) n=23	0.3 (-1.4, 1.9)
Left foot timed eyes closed dynamic balance (sec)*	11-13	3.7 (3.3, 4.2) n=311	4.3 (3.0, 5.5) n=60	0.6 (-0.8, 1.9)	4.0 (3.5, 4.5) n=205	4.8 (2.8, 6.8) n=41	0.8 (-1.3, 2.8)
	14-16	3.2 (2.5, 4.0) n=97	4.1 (3.1, 5.1) n=29	0.9 (-0.4, 2.1)	4.1 (3.3, 4.9) n=105	4.0 (2.2, 5.8) n=23	-0.1 (-2.1, 1.9)

*Data is not normally-distributed; therefore, the measure of central tendency presented is the median (99% CI)

Table 4.7 SEBT measures for injured and uninjured groups stratified by age and sex

Outcome measure	Age group (years)	Mean (99% CI)					
		Females			Males		
		Uninjured	Injured	Difference	Uninjured	Injured	Difference
SEBT Right foot composite normalized reach distance (%)	11-13	77.6 (74.7, 80.6) n=88	79.8 (76.0, 83.7) n=26	2.2 (-3.5, 7.9)	77.8 (74.8, 80.8) n=76	78.7 (72.3, 85.1) n=15	0.9 (-6.3, 8.2)
	14-16	78.0 (74.2, 81.8) n=31	73.4 (69.2, 77.6) n=21	-4.6 (-10.2, 0.9)	80.8 (75.9, 85.6) n=37	83.4 (74.2, 92.6) n=11	2.6 (-7.3, 12.4)
SEBT Left foot composite normalized reach distance (%)	11-13	76.7 (73.6, 79.9) n=87	77.1 (72.7, 81.5) n=26	0.3 (-5.8, 6.4)	76.1 (72.9, 79.3) n=76	78.4 (72.8, 84.0) n=15	2.26 (-5.3, 9.8)
	14-16	76.0 (71.1, 80.9) n=31	73.3 (67.9, 78.7) n=21	-2.7 (-9.9, 4.4)	78.4 (73.1, 83.7) n=37	79.9 (70.8, 89.0) n=11	1.5 (-9.0, 12.1)
SEBT anterior reach distance difference (Left-Right) (cm)	11-13	-1.1 (-2.9, 0.8) n=87	-2.3 (-4.6, 0.0) n=26	-1.2 (-4.7, 2.4)	-0.8 (-2.2, 0.5) n=79	0.1 (-3.3, 3.4) n=16	-0.9 (-2.4, 4.2)
	14-16	0.2 (-2.0, 2.3) n=31	-1.2 (-5.3, 2.9) n=20	-1.4 (-5.4, 2.6)	-0.6 (-3.4, 2.2) n=37	-1.5 (-6.6, 3.6) n=11	-0.9 (-6.4, 4.6)
SEBT lateral reach distance difference (Left-Right) (cm)	11-13	-1.0 (-2.7, 0.8) n=87	-1.7 (-6.0, 2.5) n=26	-0.8 (-3.2, 4.7)	-1.3 (-3.4, 0.7) n=79	-1.3 (-5.8, 3.2) n=16	0.0 (-4.9, 4.9)
	14-16	-5.3 (-14.4, 3.7) n=31	0.7 (-4.5, 6.0) n=20	-6.1 (-5.6, 17.7)	-3.0 (-6.5, 0.6) n=37	-5.1 (-13.3, 3.2) n=11	2.1 (-9.5, 5.2)

Table 4.7 Continued

Outcome measure	Age group (years)	Mean (99% CI)					
		Females			Males		
		Uninjured	Injured	Difference	Uninjured	Injured	Difference
SEBT medial reach distance difference (Left-Right) (cm)	11-13	-0.5 (-2.9, 1.9) n=87	-2.8 (-6.2, 0.5) n=26	-2.3 (-7.0, 2.4)	-1.3 (-4.4, 1.7) n=79	-0.2 (-7.4, 7.0) n=16	1.2 (-6.2, 8.5)
	14-16	0.6 (-2.0, 3.1) n=31	-0.3 (-3.9, 3.3) n=20	-0.9 (-5.0, 3.2)	-0.6 (-4.8, 6.2) n=37	-4.0 (-10.8, 2.8) n=11	-3.4 (-11.7, 4.9)

4.4.2 Multivariable Analyses

Multivariable logistic and linear regression analyses were performed to assess the association between previous injury (injured/uninjured) and each of the outcome variables (adjusting for weekly hours of sport participation, age group, and sex). These variables were chosen based on clinical relevance. Sport participation was dichotomized using 1 hour of participation per week as the cut point, which was rounded up from the 25th percentile of 0.85 mean hours of sport participation per week. Participants reported weekly hours of sport participation outside of PE class for a variety of sports, and the number of weeks per year that they participated in each sport. This was used to calculate mean weekly hours of sport participation. Those whose calculated mean weekly sport participation was less than one hour per week were categorized as low sport participation, and those whose calculated mean weekly sport participation was greater or equal to 1 hour per week were categorized as high sport participation. Age group was dichotomized into 11-13 year olds and 14-16 year olds based on the median of 13 years. The baseline groups selected for the multivariable regression analyses included those who participated in less than one hour of sport per week, females, and participants in the 11-13 year old category for age group.

4.4.2.1 Primary multivariable logistic regression analyses

Multivariable logistic regression analyses were performed to examine the association between previous injury and each of the dichotomized health outcome measures (BMI and waist circumference category). Each of the models for the multivariable analyses adjusted for sport participation, age group, and sex. Relationships

between previous injury and BMI category and between previous injury and waist circumference category were assessed for potential effect modification by sex and for potential confounding from sport participation, age, and sex. A variable was determined to be a confounder if the exposure coefficient of previous injury (β_1) changed by more than 10% when the potential confounder was removed from the model. Estimated odds ratios, adjusted for dichotomized age group, dichotomized sport participation, and sex, are reported in Table 4.8.

Sport participation confounded the relationship between previous injury and BMI, and was also significant in the final model. Although there was no evidence of effect modification or confounding, age and sex were included in the final model due to their clinical relevance. The odds of having an unhealthy BMI were significantly increased in previously injured participants compared to those who reported no previous injury (OR=1.82, 99% CI 1.07, 3.11). A significant relationship was demonstrated between previous injury and BMI category at a 0.01 alpha level ($p<0.001$).

Sport participation, age group, and sex all confounded the relationship between previous S&R injury and waist circumference category, yet none of these variables were significant. The relationship between previous S&R injury and waist circumference category was not significant at the 0.01 alpha level. Further, there was no significant difference in the odds of having an unhealthy waist circumference for previously injured versus uninjured participants.

Coding for each of the models:

- Injury: 0=uninjured, 1=injured
- Sex: 0=Female, 1=Male
- Age group: 0=11-13 years, 1=14-16 years
- Sport participation: 0=low (<1 hour/week), 1=high ($\geq$ 1 hour/week)

Log odds of BMI being unhealthy = $(0.2119904) + (1.821348 \cdot \text{Injury}) + (1.437877 \cdot \text{Sex})$
 $+ (0.7846073 \cdot \text{Age group}) + (0.6854399 \cdot \text{Sport participation})$

Log odds of waist circumference being unhealthy = $(0.0123388) + (1.085792 \cdot \text{Injury})$
 $+ (1.848003 \cdot \text{Sex}) + (1.532596 \cdot \text{Age group}) + (1.077097 \cdot \text{Sport participation})$

Table 4.8 Odds ratios based on multivariable logistic regression models describing body composition measures (adjusted for sport participation, age, and sex)

Outcome Measure		Adjusted OR (99% CI)
BMI category (% unhealthy)	Uninjured	1.0
	Injured	1.82 (1.07, 3.11)
WC category (% unhealthy)	Uninjured	1.0
	Injured	1.08 (0.25, 4.70)

4.4.2.2 Primary multivariable linear regression analysis

Multivariable linear regression analyses were performed to examine the association between previous injury and each of the continuous health and physical fitness outcome measures (BMI, waist circumference, predicted VO₂max, vertical jump height, ECDB, SEBT right and left normalized composite reach distances, and SEBT mean differences for each reach direction). Linear regression assumptions were assessed, and were satisfied for all models with the exception of the ECDB. In this instance, the assumption of constant variance was violated, thus the outcome variables were log transformed and are presented in the Table 4.10 in the log scale. BMI z-score and waist circumference were assessed for effect modification by sex, while the analyses of the remaining outcomes (predicted VO₂max, vertical jump height, ECDB, and SEBT measures) were assessed for effect modification by sex and sport participation. All analyses assessed for confounding and significance of sport participation, age group, and sex. Tables 4.9-4.11 summarize the regression coefficients for injury status, the estimated means and 99% confidence intervals by injury group for each outcome measure. Analyses were adjusted for sport participation, age group, and sex. P-values describing the significance of the relationship between previous injury and the outcome variable of interest are also reported, in addition to adjusted R² values to describe the fit of the model.

The coefficients for injury status (β_1) reported in Tables 4.9-4.11 represent the difference in the expected means of each outcome measure due to belonging to different injury status groups, adjusted by sport participation, age group, and sex. Based on an alpha level of 0.01, those that demonstrated a statistically significant increase for injured

compared to uninjured participants were BMI z-score and left foot ECDB. No significant differences in means between injury group were demonstrated when sport participation, age group, and sex are held constant (11-13 year old females with low weekly hours of sport participation). There was no evidence of effect modification in any of the relationships examined. Although sport participation, age, and sex were included in all models, their relationships differed within each. Equations describing the final regression models, including sport participation, age group, and sex, are reported below.

Coefficients associated with each of the variables in the final model describe the changes in the outcome that occurred based on the variable in question.

Sport participation was a confounder in the relationship between previous injury and predicted VO_2max , right and left foot composite reach distances on the SEBT, and differences in the anterior and lateral reach directions for the SEBT, and was significant in the final predicted VO_2max model. Age group confounded the relationship between previous injury and vertical jump height, right foot ECDB, right and left composite SEBT reach distances, and differences in lateral and medial reach directions for SEBT. Age group was significant in the waist circumference, and vertical jump models. Sex was significant in the models for BMI z-score, waist circumference, predicted VO_2max , vertical jump, and right foot ECDB tests, and confounded the relationships between previous injury and predicted VO_2max , vertical jump height, and both right and left foot composite reach distance for the SEBT. Sport participation, age group, and sex remained in all models due to their clinical relevance, regardless of confounding or statistical significance.

$$\text{BMI z-score} = (0.223449) + (0.02942303 * \text{Injury}) + (0.1966918 * \text{Sex}) \\ + (-0.1110579 * \text{Age group}) + (-0.1087616 * \text{Sport participation})$$

$$\text{Waist circumference} = (67.47405) + (1.642513 * \text{Injury}) + (2.271615 * \text{Sex}) + \\ (2.811613 * \text{Age group}) + (-1.241775 * \text{Sport participation})$$

Table 4.9 Coefficients of injury and means between injured and uninjured participants in multivariable linear regression models describing health outcome measures, adjusted for sport participation, age, and sex

Outcome Measure	Exposure variable				Model characteristic
	Injury coefficient (99% CI)	Uninjured Mean (99% CI)	Injured Mean (99% CI)	P-value	Adjusted R ²
BMI z-score	0.29 (0.07, 0.52)	0.22 (0.01, 0.44)	0.52 (0.23, 0.81)	<0.001	0.0176
Waist circumference (cm)	1.6 (-0.2, 3.5)	67.5 (65.8, 69.2)	69.1 (66.8, 71.4)	0.020	0.0489

$$\text{VO}_{2\text{max}} = (43.51782) + (0.7434408 * \text{Injury}) + (3.917763 * \text{Sex}) + (-0.1279398 * \text{Age group}) + (3.524188 * \text{Sport participation})$$

$$\text{Vertical Jump} = (28.1121) + (0.5862733 * \text{Injury}) + (5.668231 * \text{Sex}) + (3.865603 * \text{Age group}) + (1.411798 * \text{Sport participation})$$

$$\text{Right foot eyes closed dynamic balance} = (1.279367) + (0.0657489 * \text{Injury}) \\ + (0.1641536 * \text{Sex}) + (0.0177344 * \text{Age group}) + (0.0052442 * \text{Sport participation})$$

Left foot eyes closed dynamic balance = (1.33149) + (0.154105*Injury)

+ (0.0975506*Sex) + (-0.0450097*Age group)+(0.008673*Sport participation)

Table 4.10 Coefficients of injury and means between injured and uninjured participants in multivariable linear regression models describing fitness outcome measures (adjusted for sport participation, age, and sex)

Outcome Measure	Exposure variable				Model characteristic
	Injury coefficient (99% CI)	Uninjured Mean (99% CI)	Injured Mean (99% CI)	P-value	Adjusted R ²
VO ₂ max (mL/kg/min)	0.74 (-0.42, 1.9)	43.5 (42.4, 44.6)	44.3 (42.8, 45.7)	0.100	0.1876
Vertical jump height (cm)	0.6 (-1.0, 2.2)	28.1 (26.6, 29.6)	28.7 (26.7, 30.7)	0.339	0.1848
Right foot timed eyes closed dynamic balance (sec) *log-transformed	0.07 (-0.08, 0.21)	1.3 (1.1, 1.4)	1.4 (1.2, 1.5)	0.239	0.0147
Left foot eyes closed dynamic balance (sec) *log-transformed	0.15 (0.01, 0.30)	1.3 (1.2, 1.5)	1.5 (1.3, 1.6)	0.005	0.0111

SEBT right composite reach = (77.98264) + (0.1286777 *Injury) + (1.243265*Sex)

+ (0.5349877*Age group)+(-0.8754489*Sport participation)

SEBT left composite reach = (75.83974)+(-0.1551884*Injury) + (0.6767176*Sex)

+ (0.1991453*Age group) + (0.6110627*Sport participation)

SEBT anterior reach difference = (-1.222071) + (-0.7447837*Injury)

+ (0.0680067*Sex) + (0.5999309*Age group) + (0.2881355*Sport participation)

SEBT lateral reach difference = (-1.426642) + (0.510995*Injury) + (-0.2563107 *Sex)

+ (-2.097562*Age group) + (0.4184999*Sport participation)

SEBT medial reach difference = (-1.350489) + (-1.161753 *Injury) + (-0.4296988*Sex)

+ (1.058834*Age group) + (0.8143378*Sport participation)

Table 4.11 Coefficients of injury and means between injured and uninjured participants in multivariable linear regression models describing fitness outcome measures (adjusted for sport participation, age, and sex)

Outcome Measure	Exposure variable				Model characteristic
	Injury coefficient (99% CI)	Uninjured Mean (99% CI)	Injured Mean (99% CI)	P-value	Adjusted R ²
SEBT Right foot composite normalized reach distance (%)	0.1 (-3.3, 3.6)	78.0 (74.8, 81.1)	78.1 (73.9, 82.3)	0.923	<0.0001
SEBT Left foot composite normalized reach distance (%)	-0.2 (-3.9, 3.6)	75.8 (72.4 79.2)	75.7 (71.1, 80.2)	0.915	<0.0001
SEBT anterior reach distance difference (Left-Right) (cm)	-0.7 (-2.7, 1.2)	-1.2 (-3.0, 0.6)	-2.0 (-4.3, 0.4)	0.327	<0.0001
SEBT lateral reach distance difference (Left-Right) (cm)	0.5 (-2.7, 3.8)	-1.4 (-4.4, 1.5)	-0.9 (-4.8, 3.0)	0.683	<0.0001
SEBT medial reach distance difference (Left-Right) (cm)	-1.2 (-4.2, 1.9)	-1.4 (-4.2, 1.5)	-2.5 (-6.2, 1.2)	0.328	<0.0001

4.4.3 Exploratory Analyses

An exploratory analysis was used to examine the association between three previous injury-related exposure variables including number of injuries, time since most recent injury, and severity of most recent injury, and each of the outcome variables. The exploratory analyses included logistic regression analyses for BMI and waist circumference categories, and linear regression analyses for the remaining outcome variables (BMI z-score, waist circumference, predicted VO₂max, vertical jump height, log-transformed ECDB, SEBT right and left normalized composite reach distances, and SEBT mean differences for each reach direction). Each also adjusted for sport participation, age group, and sex, and assessed each of these independent variables for confounding. Logistic regressions for BMI category and waist circumference category, and linear regressions for BMI z-score and waist circumference also assessed for effect modification by sex, while the remaining linear regressions for fitness and balance outcomes assessed for effect modification by sex and by sport participation.

4.4.3.1 Exploratory multivariable logistic regression analyses

Multivariable logistic regression analyses were performed to examine the association between time since most recent injury, severity of injury, and number of injuries, with each of the dichotomized health outcome measures (BMI and waist circumference category). Odds ratios for the three exploratory injury variables as well as odds ratios adjusted by sport participation, age group, and sex, are reported in Table 4.11 for each of the exposure variables. P-values were also reported for each of the injury exposure variables and the outcome variables.

There was no evidence of effect modification or confounding in the analysis for BMI category and none of the independent variables were significant based on an alpha level of 0.01 when adjusting for sport participation, age, and sex. In the model for waist circumference category; sport participation, age, and sex confounded severity of injury, while sport participation and age group also confounded number of injuries. None of the independent variables were significant in the final model. None of the participants who had sustained two injuries and had an unhealthy waist circumference, thus the coefficient describing the log odds of sustaining two injuries was omitted from the unadjusted and adjusted waist circumference models.

4.4.3.2 Exploratory multivariable linear regression analysis

Multivariable linear regression analyses were used to examine the relationships between the three injury exposure variables (time since injury, severity of injury, and number of injuries) and each of the continuous outcome variables. Unadjusted estimated changes (β_1) and estimated changes adjusted for sport participation, age group, and sex with 99% confidence intervals are reported in Tables 4.13-4.15. P-values for the exposure-outcome relationships are also reported.

Linear regression assumptions were assessed, and assumptions were satisfied for each of the outcome variables, with the exception of the right and left foot ECDB. The assumption of constant variance was violated, thus the variable was log transformed. Exposure-outcome relationships that were significant in the final models, based on a 0.01 alpha level, included associations between number of injuries and BMI z-score, and number of injuries and waist circumference. Due to their clinical relevance, all final models included participation, age group, and sex as independent variables; however,

each of these variables were also assessed for confounding in the analyses. Additionally, sex was assessed for effect modification of injury status effect on outcome in the BMI z-score and waist circumference models, while both sex and sport participation were assessed for effect modification of injury status effect in each of the fitness and balance models.

Equations derived from the final models of the exploratory analysis are reported below. There was no evidence of modification in any of the relationships; however, there was evidence of confounding. Table 4.16 summarizes the confounding variables in each of the relationships. Sport participation was statistically significant in the predicted VO₂max model. Age group was statistically significant in the models for waist circumference and vertical jump, and sex was significant in the models for waist circumference, predicted VO₂max, vertical jump, and right foot ECDB.

For the multivariable logistic regression equations, the coefficients for the independent variables (sport participation, age, and sex) represent a change in the log odds of the outcome variable per unit increase of the exposure variable (time since injury, injury severity, and number of injuries). For the multivariable linear regression equations, the coefficients for the independent variables (sport participation, age, and sex) represent a change in the estimated mean of the outcome variable per unit increase of the exposure variable (time since injury, injury severity, and number of injuries).

4.4.3.2.1 Coding for each of the models:

- Number of injuries: 0=no injuries, 1=one injury, 2=two injuries
- Time since most recent injury: continuous; days
- Severity of most recent injury: continuous; days

- Sex: 0=Female, 1=Male
- Age group: 0=11-13 years, 1=14-16 years
- Sport participation: 0=low (0 to 1 hour/week), 1=high (≥ 1 hour/week)

BMI category = $(-1.482719) + (\beta_1 * \text{Number of Injuries}) + (-0.000834 * \text{Time since injury})$
 $+ (-0.01289 * \text{Severity of injury}) + (0.2959733 * \text{Sex}) + (-0.1555531 * \text{Age group})$
 $+ (-0.4496632 * \text{Sport participation})$

β_1 for Number of injuries: 1=0.8915907, 2=1.801126

Waist circumference category = $(-4.503537) + (\beta_1 * \text{Number of Injuries})$
 $+ (-0.011085 * \text{Time since injury}) + (-0.0044721 * \text{Severity of injury}) + (0.3784896 * \text{Sex})$
 $+ (0.632829 * \text{Age group}) + (0.2173741 * \text{Sport participation})$

β_1 for Number of injuries: 1=0.5315894, 2=omitted

Table 4.12 Unadjusted and adjusted odds ratios from exploratory multivariable logistic regression models describing health outcome measures

Outcome measure			Unadjusted		Adjusted	
			Exposure variable		Exposure variable	
			Coefficient (99% CI)	P-value	Coefficient (99% CI)	P-value
BMI category	Time since		0.999 (0.995, 1.004)	0.673	0.999 (0.994, 1.004)	0.656
	Severity		0.993 (0.961, 1.026)	0.587	0.987 (0.948, 1.028)	0.416
	Frequency	1	2.115 (0.745, 6.008)	0.064	2.439 (0.814, 7.306)	0.036
		2	5.219 (0.754, 36.121)	0.028	6.05 (0.836, 43.86)	0.019
WC category	Time since		0.988 (0.950, 1.028)	0.435	0.989 (0.952, 1.027)	0.451
	Severity		0.990 (0.790, 1.242)	0.912	0.996 (0.808, 1.227)	0.956
	Frequency	1	1.891 (0.039, 91.679)	0.672	1.702 (0.036, 79.546)	0.722
		2	n/a	n/a	n/a	n/a

$$\begin{aligned} \text{BMI z-score} = & (0.2451836) + (\beta_1 * \text{Number of Injuries}) + (0.0000623 * \text{Time since injury}) \\ & + (-0.0082195 * \text{Severity of injury}) + (0.1794544 * \text{Sex}) + (-0.0749693 * \text{Age group}) \\ & + (-0.1370197 * \text{Sport participation}) \end{aligned}$$

β_1 for Number of injuries: 1=0.361326, 2=1.053641

$$\begin{aligned} \text{Waist circumference} = & (67.59233) + (\beta_1 * \text{Number of Injuries}) + (-0.0059043 * \text{Time since} \\ & \text{injury}) + (-0.0656726 * \text{Severity of injury}) + (2.184327 * \text{Sex}) + (3.080304 * \text{Age group}) \\ & + (-1.434891 * \text{Sport participation}) \end{aligned}$$

β_1 for Number of injuries: 1=3.83621, 2=8.050948

Table 4.13 Unadjusted and adjusted injury coefficients from exploratory multivariable linear regression models describing health outcome measures

Outcome measure			Unadjusted			Adjusted		
			Exposure variable		Model characteristics	Exposure variable		Model characteristics
			Coefficient (99% CI)	P-value	R ²	Coefficient (99% CI)	P-value	Adjusted R ²
BMI z-score	Time since		0.000 (-0.002, 0.002)	0.925	0.0152	6.23x10 ⁻⁵ (-0.0021, 0.0022)	0.941	0.0282
	Severity		-0.007 (-0.019, 0.004)	0.115		-0.008 (-0.020, 0.004)	0.078	
	Frequency	1	0.324 (-0.157, 0.805)	0.082		0.361 (-0.128, 0.851)	0.057	
		2	1.023 (0.027, 2.019)	0.008		1.054 (0.064, 2.043)	0.006	
WC (cm)	Time since		-0.007 (-0.025, 0.010)	0.273	0.0142	-0.006 (-0.023, 0.011)	0.376	0.0595
	Severity		-0.058 (-0.155, 0.039)	0.124		-0.066 (-0.163, 0.031)	0.080	
	Frequency	1	3.927 (0.028, 7.826)	0.009		3.836 (0.070, 7.742)	0.011	
		2	8.333 (0.327, 16.339)	0.007		8.051 (0.220, 15.882)	0.008	

$$\text{VO}_2\text{max} = (43.41705) + (\beta_1 * \text{Number of Injuries}) + (0.0047808 * \text{Time since injury})$$

$$+ (0.0185535 * \text{Severity of injury}) + (3.91684 * \text{Sex}) + (0.0316561 * \text{Age group})$$

$$+ (3.556685 * \text{Sport participation})$$

$$\beta_1 \text{ for Number of injuries: } 1 = -0.0084435, 2 = -1.221672$$

$$\text{Vertical Jump} = (28.07553) + (\beta_1 * \text{Number of Injuries}) + (-0.0056745 * \text{Time since injury})$$

$$+ (0.0003325 * \text{Severity of injury}) + (5.726577 * \text{Sex}) + (3.763565 * \text{Age group})$$

$$+ (1.473761 * \text{Sport participation})$$

$$\beta_1 \text{ for Number of injuries: } 1 = 1.977711, 2 = -0.3781473$$

$$\text{Right foot eyes closed dynamic balance} = (1.283601) + (\beta_1 * \text{Number of Injuries})$$

$$+ (-0.0002668 * \text{Time since injury}) + (-0.0012617 * \text{Severity of injury})$$

$$+ (0.1482818 * \text{Sex}) + (0.0163771 * \text{Age group}) + (0.0137196 * \text{Sport participation})$$

$$\beta_1 \text{ for Number of injuries: } 1 = 0.1636114, 2 = -0.0336408$$

$$\text{Left foot eyes closed dynamic balance} = (1.310228) + (\beta_1 * \text{Number of Injuries})$$

$$+ (-0.0002398 * \text{Time since injury}) + (0.0028788 * \text{Severity of injury}) + (0.105029 * \text{Sex})$$

$$+ (-0.0513386 * \text{Age group}) + (0.0338974 * \text{Sport participation})$$

$$\beta_1 \text{ for Number of injuries: } 1 = 0.2095422, 2 = 0.60517$$

Table 4.14 Injury coefficients from exploratory multivariable linear regression models describing fitness outcome measures

Outcome measure			Unadjusted			Adjusted		
			Exposure variable		Model characteristics	Exposure variable		Model characteristics
			Coefficient (99% CI)	P-value	R ²	Coefficient (99% CI)	P-value	Adjusted R ²
VO ₂ max (mL/kg/min)	Time since		-0.004 (-0.007, 0.016)	0.342	0.0022	0.005 (-0.006, 0.016)	0.261	0.1889
	Severity		0.018 (-0.044, 0.080)	0.457		0.019 (-0.039, 0.076)	0.405	
	Frequency	1	0.204 (-2.556, 2.964)	0.849		-0.008 (-2.599, 2.581)	0.993	
		2	-1.353 (-7.236, 4.530)	0.553		-1.222 (-6.596, 4.153)	0.557	
Vertical jump height (cm)	Time since		-0.007 (-0.024, 0.010)	0.273	0.0041	-0.006 (-0.021, 0.010)	0.339	0.1858
	Severity		0.001 (-0.091, 0.092)	0.981		0.000 (-0.084, 0.084)	0.992	
	Frequency	1	2.489 (-1.216, 6.194)	0.083		1.978 (-1.451, 5.407)	0.137	
		2	0.087 (-7.452, 7,625)	0.976		-0.378 (-7.190, 6.433)	0.88	
Right foot timed ECDB (sec) *log transformed	Time since		-0.000 (-0.001, 0.001)	0.901	0.0038	-0.000 (-0.002, 0.001)	0.608	0.0094
	Severity		-0.002 (-0.008, 0.005)	0.574		-0.001 (-0.008, 0.006)	0.641	
	Frequency	1	0.142 (-0.156, 0.440)	0.219		0.164 (-0.139, 0.466)	0.162	
		2	-0.072 (-0.731, 0.586)	0.777		-0.034 (-0.685, 0.618)	0.894	

Table 4.14 Continued

Outcome measure			Unadjusted			Adjusted		
			Exposure variable		Model characteristics	Exposure variable		Model characteristics
			Coefficient (99% CI)	P-value	R ²	Coefficient (99% CI)	P-value	Adjusted R ²
Left foot timed ECDB (sec) *log transformed	Time since		-0.000 (-0.002, 0.001)	0.646	0.0207	-0.000 (-0.002, 0.010)	0.640	0.0202
	Severity		0.002 (-0.005, 0.009)	0.453		0.003 (-0.004, 0.008)	0.282	
	Frequency	1	0.233 (0.060, 0.525)	0.040		0.210 (-0.089, 0.508)	0.070	
		2	0.619 (-0.027, 1.266)	0.014		0.605 (-0.038, 1.249)	0.015	

SEBT right composite reach = (77.52902) + (β_1 *Number of Injuries) + (-0.179493*Time since injury) + (0.1428559*Severity of injury) + (1.50545*Sex) + (1.3523*Age group) + (-0.5926708*Sport participation)

β_1 for Number of injuries: 1=2.307558, 2=3.358764

SEBT left composite reach = (75.48997) + (β_1 *Number of Injuries) + (-0.0086253*Time since injury) + (0.0933677*Severity of injury) + (0.8492812*Sex) + (0.7277659*Age group) + (0.9918537*Sport participation)

β_1 for Number of injuries: 1=1.835536, 2=-2.358833

SEBT anterior reach difference = (-0.985303) + (β_1 *Number of Injuries) + (0.0074341*Time since injury) + (-0.0975805*Severity of injury) + (-0.109825*Sex) + (0.4215972*Age group) + (0.1664385*Sport participation)

β_1 for Number of injuries: 1=-0.3378679, 2=-3.389243

SEBT lateral reach difference = (-1.43897) + (β_1 *Number of Injuries) + (0.0108058*Time since injury) + (-0.104459*Severity of injury) + (-0.1081188*Sex) + (-2.811845*Age group) + (0.693031*Sport participation)

β_1 for Number of injuries: 1=0.2712, 2=-3.820745

SEBT medial reach difference = (-1.133192) + (β_1 *Number of Injuries) + (0.0095987*Time since injury) + (0.0240919*Severity of injury) + (-0.3085293*Sex) + (1.052404*Age group) + (0.7954321*Sport participation)

β_1 for Number of injuries: 1=-2.463955, 2=-7.346687

Table 4.15 Injury coefficients from exploratory multivariable linear regression models describing SEBT outcome measures

Outcome measure			Unadjusted			Adjusted		
			Exposure variable		Model characteristics	Exposure variable		Model characteristics
			Coefficient (99% CI)	P-value	R ²	Coefficient (99% CI)	P-value	Adjusted R ²
SEBT Right foot composite normalized reach distance (%)	Time since		-0.018 (-0.058, 0.021)	0.224	0.0041	-0.018 (-0.057, 0.021)	0.237	<0.0001
	Severity		0.127 (-0.218, 0.471)	0.342		0.143 (-0.203, 0.489)	0.285	
	Frequency	1	2.372 (-5.207, 9.950)	0.418		2.308 (-5.294, 9.909)	0.432	
		2	3.075 (-9.490, 15.642)	0.526		3.359 (-9.245, 15.962)	0.490	
SEBT Left foot composite normalized reach distance (%)	Time since		-0.008 (-0.051, 0.034)	0.598	0.0054	-0.009 (-0.052, 0.034)	0.603	<0.0001
	Severity		0.086 (-0.286, 0.459)	0.547		0.093 (-0.283, 0.470)	0.521	
	Frequency	1	1.813 (-6.371, 9.996)	0.566		1.836 (-6.448, 10.119)	0.566	
		2	2.461 (-16.065, 11.143)	0.639		-2.359 (-16.129, 11.412)	0.657	
SEBT anterior reach distance difference (Left-Right) (cm)	Time since		0.008 (-0.014, 0.030)	0.360	0.0146	0.007 (-0.015, 0.030)	0.394	<0.0001
	Severity		-0.100 (-0.295, 0.096)	0.187		-0.098 (-0.296, 0.101)	0.204	
	Frequency	1	-0.441 (-4.707, 3.825)	0.789		-0.338 (-4.672, 3.996)	0.840	
		2	-3.434 (-10.568, 3.701)	0.213		-3.389 (-10.568, 3.700)	0.226	

Table 4.15 Continued

Outcome measure			Unadjusted			Adjusted		
			Exposure variable		Model characteristics	Exposure variable		Model characteristics
			Coefficient (99% CI)	P-value	R ²	Coefficient (99% CI)	P-value	Adjusted R ²
SEBT lateral reach distance difference (Left-Right) (cm)	Time since		0.009 (-0.028, 0.046)	0.515	0.0064	0.011 (-0.027, 0.048)	0.457	0.0004
	Severity		-0.083 (-0.409, 0.242)	0.509		-0.104 (-0.436, 0.227)	0.414	
	Frequency	1	0.208 (-6.898, 7.313)	0.940		0.271 (-6.953, 7.495)	0.922	
		2	-3.888 (-15.771, 7.995)	0.397		-3.820 (-15.902, 8.260)	0.413	
SEBT medial reach distance difference (Left-Right) (cm)	Time since		0.011 (-0.023, 0.045)	0.419	0.0109	0.010 (-0.026, 0.045)	0.480	<0.0001
	Severity		0.020 (-0.284, 0.325)	0.864		0.024 (-0.286, 0.334)	0.840	
	Frequency	1	-2.468 (-9.115, 4.179)	0.336		-2.464 (-9.222, 4.295)	0.345	
		2	-7.156 (-18.272, 3.960)	0.096		-7.347 (-18.649, 3.955)	0.093	

Table 4.16 Summary of confounders [✓] for exploratory analyses

Potential confounder	Sport participation			Age group			Sex		
Exposure variable	Time since injury	Injury severity	Number of injuries	Time since injury	Injury severity	Number of injuries	Time since injury	Injury severity	Number of injuries
BMI z-score	✓	✓		✓			✓		
BMI category									
WC (cm)	✓	✓	✓	✓					
WC category			✓		✓	✓		✓	
VO ₂ max		✓	✓			✓			✓
Vertical Jump height	✓	✓	✓	✓	✓	✓		✓	✓
ECDB Right	✓	✓	✓	✓	✓		✓		✓
ECDB Left	✓	✓	✓	✓		✓			
SEBT right composite reach									
SEBT left composite reach			✓						
SEBT anterior reach distance difference						✓			
SEBT lateral reach distance difference			✓	✓	✓	✓			
SEBT medial reach distance difference					✓				

Chapter Five: **Discussion**

The objective of this study was to assess the influence of previous sport and recreational (S&R) injury on a number of health and physical fitness measures in junior high school students. To the best of our knowledge this is the first study to evaluate this relationship in this population. There is a lack of research that investigates injury as a risk for poor health and physical fitness outcomes in youth. As identified in the literature review, the published research that has been conducted assesses balance and postural stability, kinematic measures, performance, and return to play, and focuses primarily on elite athletes or recreationally active adults.

Findings from this study demonstrated that previously injured participants have a significantly larger mean body mass index (BMI) and significantly increased duration for left foot eyes closed dynamic balance (ECDB) times. There were no significant differences between junior high school students who had sustained a S&R injury in the past year compared to their classmates who had not sustained an injury on measures of waist circumference, predicted VO₂max, vertical jump height, right foot ECDB, or any of the star excursion balance test (SEBT) reach distances.

5.1 Participant characteristics and participation

Participants from six junior high schools in Calgary were assessed for at least one health and physical fitness measurement and reported information on previous S&R injury, thus including them in the final sample (n=1039). The 2014/2015 cohort study included 321 participants and the 2008/2009 cohort study included 718 participants. In total, 584 (56.2%) were female and 455 (43.8%) were male. By school grade, 309 (38.1%) were in grade seven, 347 (33.5%) were in grade eight, and 294 (28.4%) were in grade nine. The mean age of the total sample was 12.9 years (99% CI 12.8, 13.0). Age, height, and weight were similar among

participants who reported a previous injury and those who did not; however, mean weekly hours of sport participation was significantly higher in the previous injury groups (4.2, 95% CI 3.1, 5.4 versus 2.4, 95% CI 2.1, 2.7). Similar proportions of males and females reported previous injury (17.4% and 18.7%, respectively). These differences are lower in comparison to proportions reported in a previous study assessing sport injury in junior high school students, where 42.02% of males and 61.14% of females reported sustaining a sport or recreational injury in the previous year.⁶

5.2 Previous injury

Approximately 18% (188/1039) of study participants reported sustaining a S&R injury that required medical attention or resulted in at least one day of time loss from physical activity (PA) participation in the previous year. This number is lower than the proportion of injuries reported in a previous study that examined a similar population, where 60.85% (95% CI 58.29, 63.35) of Calgary junior high school students reported sustaining an injury.⁶ This definition was general to any sport injury and did not necessarily fit the definition specified for the current study (any injury sustained through a sport or recreational activity that resulted in time loss from physical activity participation or required medical attention). The Canadian Community Health Survey reported that 27% of Canadian adolescents aged 12-17 sustain an injury; 66% of which are related to sport or recreational activities.¹

The most common injury types reported in this study were ligament sprains (41.5%), muscle/tendon strains (17.0%), and fractures (14.8%). Ankle and knee injuries were the most commonly injured body part (19.6% and 17.3%, respectively). This is similar to study results reported in a cross-sectional study including junior high school students, which found the most common type of injury was a ligament sprain (23.9%) followed by fractures (16.03%) and

muscle strains (14.7%), and the most commonly injured body part was the ankle (21.2%), followed by the knee (15.7%)⁶.

5.3 Health and Physical Fitness Outcomes

5.3.1 Body Composition

The results of the multivariable linear regression, adjusted for age group, sex, and sport participation, identified that the mean BMI z-score of injured participants was significantly higher compared to that of uninjured participants ($\beta_1=0.29$, 99% CI 0.07, 0.52, $p<0.001$). No significant differences were observed from independent t-test results, which stratified outcomes by age group and sex. Logistic regression analyses determined that students who had sustained an injury were at significantly increased odds of being classified as overweight or obese compared to those who were not injured (OR=1.82, 99% CI 1.07, 3.11). Although the mean waist circumference of the injured group trended toward being higher compared to the uninjured group, no statistically significant differences were found based on the independent t-tests and the multivariable regression analyses. These mean differences were approximately 1.5 cm and are not clinically relevant.

Approximately 17% (n=173/1,010) of participants were categorized as overweight or obese based on BMI, while only 2% (n=22/1,033) fell into this category based on waist circumference. It is likely that participants who elected not to have their waist circumference measured due to self-esteem issues were overweight or obese, thus contributing to the smaller proportion for the waist circumference measurement. This BMI proportion is lower compared to that reported in the 2012-2013 Canadian Health Measures Survey, where 37% of 12-17 year olds were overweight or obese as categorized by BMI. In studies that reported these proportions of

more specific populations, findings are more comparable. In a cohort of Calgary junior high school students, 16.5% were classified as overweight or obese based on International Obesity Task Force (IOTF) cut-points,⁶⁹ as were 20.2% of 12 year-old adolescents from France.¹² Limited data are available for proportions of youth classified as overweight and obese as determined by waist circumference, as BMI is more commonly used to describe body composition by categories for population level data.

The differences in proportions of overweight and obese students classified by BMI versus waist circumference may be explained by the differences in the components of body composition that each is assessing. BMI is one of the least invasive and most common anthropometric measurements; however, it does not give an indication of where the fat is located.⁷⁰ The accuracy improves with increasing levels of body fat.⁷¹ There is the potential for misclassification when calculating BMI of individuals with greater musculature, since the weight is not specific to fat mass or fat-free mass, however it is unlikely that this would be an issue in the youth population. Waist circumference is considered the most valid field-based indicator of centrally located visceral adiposity in children and adolescents, and can provide an accurate representation of health risk.⁷⁰⁻⁷² Taylor et al. (2000)⁷³ reported good agreement between percent body fat as assessed by dual energy x-ray absorptiometry (DEXA) and waist circumference z-scores (0.83, $p<0.05$).⁷³ Waist circumference has been found to predict 64.8% of the variance of visceral adipose tissue ($p<0.001$) and 80.4% of total variance in subcutaneous adipose tissue, when compared to magnetic resonance imaging in 7-16 year old children and adolescents.⁷² There are known waist circumference measurement disadvantages in children and youth from school-based setting particularly related to self-esteem issues that can arise in conjunction with the measurement techniques because of the exposure of the abdominal area. This disadvantage may

explain why waist circumference is not as commonly used as BMI for body composition measurement.

Aeberli et al (2013)⁷⁴ suggested that combining BMI and waist circumference into a composite score is more accurate to predict percent body fat. The Canadian Society of Exercise Physiology (CSEP) employs this method to classify the health status for adults. Future research could create normative comparisons using a combination of BMI and waist circumference for use in children and youth in order to create a more accurate representation of body composition.

Statistically significant differences were observed when examining the association between number of injuries and body composition outcomes in the exploratory analysis. After adjusting for age category, sex, and weekly hours of sport participation, participants who reported two previous injuries had a significantly higher BMI z-score compared to participants who did not report any injuries or who only reported one injury in the previous year (mean BMI z-score=1.05, 99% CI 0.06, 2.04). Similar outcomes were demonstrated for mean waist circumference, where those who had sustained two injuries demonstrated a mean increase of 8.1 cm (99% CI 0.2, 15.9) compared to those who reported no injuries.

Several studies that examined the influence of previous injuries on BMI outcomes support our findings that BMI is increased in those who have sustained a previous injury compared to those who have not. Whittaker et al. (2015)¹⁶ found that previously injured participants were 3.75 times (95% CI 1.24, 11.3) more likely to have a BMI that classified them as overweight or obese compared to uninjured matched controls. In youth female athletes, a greater increase in BMI z-score by five units was noted in the injured group versus the uninjured group over the course of 12 months.⁴⁰ A number of studies have also examined increased BMI as a risk factor for injury, although conclusions across the literature are inconsistent. Two cross-

sectional studies^{75,76} and one cohort study¹⁹ did not find any association between elevated BMI and injury. One cross-sectional study⁷⁷ found that the odds of sustaining a sport injury were lower for obese adolescents (12-19 years old) compared to their healthy weight counterparts (OR=0.72, 95% CI 0.53, 0.99), while there was no difference between overweight and healthy weight individuals. Conversely, a prospective cohort⁶⁹ studying the same age group found that the odds of sport injury was higher in obese compared to healthy weight individuals (OR=1.34, 95% 1.02, 1.80).

Overweight and obese youth may be at an increased risk for physical activity-related injury due to functional and structural limitations, as well as physical activity participation behavioural factors. Increased mass results in a greater load on the joints, particularly in the lower limbs, increasing the potential for lower-extremity sprains/strains, and fractures.^{75,78} Additionally, when an individual with a higher BMI classification is exposed to a form of contact such as a hit during a sporting activity, the forces generated would be greater because of the increased body mass, resulting in increased torque on the bones, thus intensifying the amount of damage to the joints.⁷⁵ The evidence that does not support an association between BMI and injury may be explained by the concept that some overweight and obese individuals may choose to limit their participation in certain physical activities due to the limitations caused by their increase in body weight and size.⁷⁹ They may also be less likely to return to exercise post-injury, which may affect recovery time and therefore their return to normal daily activity.⁷⁵

5.3.2 Physical Fitness

The only significant difference observed between injury groups was left foot eyes closed dynamic balance, with injured participants demonstrating significantly longer balance times compared to uninjured participants [$\beta_1=0.15$ (99% CI 0.01, 0.30, $p=0.005$). This is in contrast to

results reported by Whittaker et al. (2015),¹⁶ who found no differences in unipedal dynamic balance times between participants who had sustained a knee injury in their youth and their matched controls. Longer balance times in the left foot may be explained by right foot dominance, in that individuals would use their left foot for stability when performing an action with their right foot, such as kicking a soccer ball. Only the 2014/2015 cohort noted participant's dominant foot, therefore it was not taken into account for the analysis and is therefore difficult to draw any conclusions based on these assumptions. However, it is important to note the significantly higher mean weekly hours of sport participation in the injured group compared to the uninjured group, which may explain that the better balance scores in the injured individuals may be a result of increased sport participation.

No statistically significant differences were noted between injury groups for any of the remaining physical fitness and balance measures, including predicted VO₂max, vertical jump height, right foot timed eyes closed dynamic balance, or any of the SEBT measures based on the multivariable linear regression analyses. Although there was no evidence of significance, it is still interesting to note that the independent t-tests displayed better mean predicted VO₂max scores and vertical jump heights in the injured compared to uninjured groups. This may be explained by the fact that those who participate in more sports or at higher levels of sport are more likely to get injured.^{69,80,81} These individuals would also likely have increased levels of aerobic capacity and musculoskeletal fitness compared to those who do not participate in sport, thus explaining the significantly higher predicted VO₂max values and higher mean vertical jump scores in the injured group. In the current study, sport category was a significant variable in the relationship between previous injury and predicted VO₂max ($p < 0.001$), and confounded the relationship between number of injuries and VO₂max. Sport participation also confounded the

relationship between each time since injury, severity of injury, and number of injuries and vertical jump height. This supports the hypothesis that number of weekly hours of sport participation may explain why predicted VO₂max values and vertical jump height is better in the injured compared to uninjured group.

No obvious patterns in differences were observed between injury groups in the SEBT balance measure. This is an interesting finding, as literature has reported mixed conclusions regarding differences in balance and postural stability between injury groups.^{16,42,43,45} Injured participants demonstrated significantly lower reach distances on the SEBT in some studies,^{42,45} but others found no differences.^{16,43} These studies were conducted in recreationally active adults and elite athletes, and likely do not reflect results that would be found in the population in this study. When examining this relationship using a prospective cohort design, poor balance is a risk factor for subsequent injury in high school and collegiate athletes.^{67,82} Although results are not comparable due to the differences in exposure-outcome variables, it is interesting that relationships were noted between balance as a risk factor for injury in other studies, but not between previous injury and balance outcomes in the present study.

Although the relationships between previous injury and the SEBT balance variables are not significant, it is important to highlight the mean scores achieved by the students in this study (Table 4.4). Plisky et al. (2006)⁶⁷ had noted that differences in anterior reach distance between right and left legs that were greater or equal to 4 cm were significantly associated with lower extremity injuries in high school basketball players (adjusted OR=2.7, 95% CI 1.4, 5.3). Additionally, normalized composite reach distances of less than or equal to 94% in the right leg were significantly associated with lower extremity injury in all participants (adjusted OR=3.0, 95% CI 1.5, 6.1). In both the injured and uninjured groups, for both age groups and for both

males and females in the current study, all normalized composite reach distances were less than 94% of limb length, with none of the 95% confidence intervals including 94%. Based on conclusions from Plisky et al. (2006),⁶⁷ this would be an indication of injury risk in the entire population. In contrast, none of the reach distance differences between right and left limbs in the anterior direction were greater or equal to 4 cm, indicating that there is no association with lower extremity injury in any of the participants. These differences in the clinical interpretations of the SEBT are interesting, suggesting that perhaps these balance tests are not sensitive enough to detect any dynamic balance differences between previously injured or uninjured individuals. This highlights the need for future studies to examine the relationship between previous injury and balance outcomes in a youth population that is not specific to athletes.

The lack of differences between injury groups may be explained by the fact that the mean time since most recent injury was 181.7 days (99% CI 153.1, 210.4) prior to the respective testing dates for each school, and the mean number of days missed was 11.9 (99% CI 7.7, 16.1). This suggests that enough time passed between the date that the most recent injury was sustained and the testing date, and that the injury was not severe enough to demonstrate any significant differences in predicted VO₂max, vertical jump, right foot dynamic balance, or any SEBT outcomes between injury groups.

5.4 Sport participation

Age group, sex, and mean weekly hours of sport participation per week (dichotomized based on a cut-point of one hour per week) were included as independent variables in the multivariable linear and logistic regression models due to their clinical significance in the associations between previous injury and each health or fitness outcome variable. These independent variables were also assessed as potential confounders in each of the relationships;

presented in Chapter 4. The significance and nature of confounding of each of these variables differed within each model, the most notable of which is hours of sport participation per week. A relationship between hours of physical activity participation and injury has been previously reported, with numerous studies concluding that increased exposure to sport or leisure time physical activity is associated with increased injury risk.^{69,75,80,81,83} Using data from the randomized controlled trial component of the 2008/2009 cohort of this study, Richmond et al. (2013)⁶⁹ reported a dose-response relationship between increasing number of sport hours per week and increased odds of injury. Specifically, those who reported participating in >0.5 to 1.6 hours of sport per week were 1.68 (95% CI 1.19, 2.37) times more likely to sustain an injury compared to those who reported less than 0.5 hours of weekly sport participation. These findings support the decision to include sport participation variable in the analyses, as it may cause a distortion in the magnitude of the outcome due to its association with injury.

5.5 Strengths

This study, to the best of our knowledge is the first to examine the influence of previous injury on health and fitness outcomes. Previously, literature has examined the influence of injury on performance and return to play in adults and elite athletes, in addition to health and physical fitness measurements as risk factors for injury.

This study included a large sample size of 1,039 participants, thus satisfying the a-priori sample size calculations and reducing the chances of Type II error (the probability of concluding that there were no differences between injury groups, when in fact significant differences existed). Including junior high school students from their PE classes ensured a more comprehensive sample that is generalizable to an urban population of Canadian youth compared to previous studies that were discussed in the literature review. The six schools were

geographically distributed around the city of Calgary, with the intent of capturing data from participants of different socio-economic and socio-demographic backgrounds.

A questionnaire was distributed to participants that asked about demographic information, physical activity participation, and injury history over the previous one year. This recall period is wide enough to capture a number of injuries that may have influenced health and physical fitness outcomes, and reduces the potential for survival bias that is noted in some studies with more narrow recall periods.^{3,46} Further, the population focus of our study also decreases the potential for survival bias because students who have sustained an injury would still be present at school to be recruited for participation. This is contrary to athletic populations, where injured participants may not be present if they had sustained an injury that was severe enough to impede them from participating in their sport. All participants who were present on the day of testing were able to complete at least one assessment, regardless of whether or not they were previously injured.

All research assistants who collected the assessments attended two training sessions to familiarize themselves with the protocols and practice delivering instructions. Instructions delivered to the students were consistent among all study personnel, and testers were assigned to the same testing stations whenever possible to increase measurement reliability. A CSEP-Certified Exercise Physiologist assessed waist circumference in all of the study participants in the 2008/2009 cohort, and a CSEP-Certified Personal Trainer assessed waist circumference in all of the study participants from the 2014/2015 cohort.

An exploratory analysis was conducted that assessed the relationship between three injury exposure variables (time since injury, injury severity, and number of injuries) and each of the outcome measures. This provided further information on details of the reported injuries.

Overall, this study has produced novel findings and provides a foundation for future research on health and physical fitness outcomes as a result of previous injury.

5.6 Limitations

Despite the fact that all efforts were made to create a well-designed study that would assess the influence of previous injury on health and physical fitness, there were still a number of limitations. Firstly, a cross-sectional study design was employed; therefore causality could not be established. It is unknown whether or not the previously injured participants had a higher mean BMI or better left foot dynamic balance compared to uninjured participants before sustaining their injury. Consent rates were low for three of the four schools in the 2014/2015 cohort (58%, 54%, and 54%, while 69% of students consented in the remaining school), and those who excluded themselves from the study may have been those who were less motivated in physical education class. There may have been the potential for selection bias, since these students who chose not to participate in the study may have exhibited different health and physical fitness attributes compared to their peers who consented to participate. Information on injury history was collected via a questionnaire, and asked participants to recall injuries sustained over the previous 12 months. This long period of time may have resulted in a recall bias. A clinician did not assess injuries sustained over this time period, thus all injuries that were reported by students in the questionnaire and met the injury definition were included in the analysis. The questionnaire only displayed three lines for students to record each injury history and previous concussions, which may have dissuaded students from reporting more injuries. Only details from the most recent injury were included in the multivariable analyses. The assumption was that the most recent injury would likely have the greatest influence on the outcomes. However, it is also possible that a more severe injury sustained prior to the most recent injury would have a greater

influence. The use of self-report questionnaires to collect injury and physical activity data are not as accurate as using objective measures. Although the questionnaire collected information on leisure-time physical activity, active transportation, and physical activity during school hours in addition to the number of weekly hours sport participation in the 2014/2015 cohort, only sport participation hours were included as an independent variable in the final analyses since this was the only physical activity exposure data that were collected at baseline in the 2008/2009 cohort. A more inclusive definition of physical activity between both cohorts may have provided an increased understanding of the influence of physical activity participation in the relationships of interest.

Due to time constraints during the days for conducting the health and physical fitness assessments as a result of short class times, each student was only able to complete one practice trial and one test trial for their SEBT assessment. Four to six practice trials and three test trials are recommended for this assessment;^{63,68,84} however, this was not feasible given the short amount of time allotted to complete the health and physical fitness assessments.

Different versions of the 20-m shuttle run were used to assess cardiorespiratory fitness; the Léger version in the 2008/2009 cohort and the Fitnessgram PACER version in the 2014/2015 cohort. Although both follow similar protocols, each test begins at a different running speed, and the Léger stage numbers and number of laps in the PACER are not consistent. Results from both tests were entered into respective equations to predict VO_2max , and were combined as a single dataset for the analysis. Both equations included age, while the Léger equation included speed (as assessed by the highest completed lap) and the PACER equation included lap number. VO_2max predicted from these two different assessments have not been combined into a singular dataset in previous studies; however, this study used the Bland-Altman method to assess

agreement between the different equations used to predict VO₂max outcomes from each tests. Although the plots (Figures 4.1 and 4.2) demonstrate that the VO₂max predicted by the PACER equation is higher compared to the VO₂max predicted by the Léger equation on the same individual for those whose 20-m shuttle run results indicate a higher mean VO₂max, the mean differences were small and the narrow limits of agreement included the null value of 0 mL/kg/min. This indicated that the slightly different protocol and VO₂max prediction equation for each test demonstrated agreement.

Multivariable linear and logistic regression analyses were used to predict the influence of previous injury on health and physical fitness outcomes; however, this study was not powered on this analysis. A conservative a-priori alpha level of $\alpha=0.01$ was used, which stemmed from a Bonferonni correction to control for the five main outcomes (BMI, waist circumference, cardiorespiratory fitness, musculoskeletal fitness, and balance). This may have failed to highlight results that were not statistically significant, but may have been practically significant. The adjusted coefficients of determination for the multivariable linear regression analyses were all very low (Tables 4.5-4.7), indicating that the proportion of variance in the outcome assessments was not well explained by the variance in the injury exposure variables. There may have been a variety of other factors that contributed to this relationship that were not adjusted for in the model.

The exploratory analysis included time since most recent injury in number of days, severity of most recent injury in number of days, and total number of injuries as exposure variables in one common multivariable regression analysis for each outcome variable. Participants who had not sustained an injury were coded as '0' for each of the three injury variables, as were participants who had reported no days missed from their most recent injury

and participants who had sustained an injury on the same day that they completed the questionnaire. This coding system is logical for injury severity, since those who did not have a very severe injury and were coded as a low number (i.e. coded as “1”, causing them to miss one day) would likely display similar trends as those who were coded ‘0’ for sustaining no injuries or for having an injury that did not require them to miss out on physical activity participation. The coding for time since most recent injury does not follow this same trend, as those who had just been injured one day previously (coded as ‘1’) would be coded similarly to participants who had not sustained an injury. This is unreasonable, as one would expect that a student who reported no previous injury would be more similar to a student who reported an injury 300 days previously compared to a student who had reported an injury one day previously. Coding the time since injury variable in this way was necessary to follow the trend of the injury severity and number of injury variables, since all three injury exposure variables were included in the same model for each outcome analysis.

This study demonstrated that previous injury influenced BMI and left foot ECDB in the junior high school population. Injured participants had a higher BMI longer balance times compared to uninjured participants. Those who sustained two injuries had a significantly higher mean BMI and waist circumference. This study was the first of its kind to examine this relationship in junior high school students, allowing results from this study to generalize to the youth population.

Chapter Six: Conclusion

6.1 Summary of Findings

This study is the first of its kind to examine the influence of previous sport and recreational (S&R) injury on health and physical fitness outcomes specifically in junior high school students. A total of 1,039 students from six Calgary junior high schools over two cohorts (2008/2009 and 2014/2015) were participants in the study. One hundred eighty-eight (18.1%) of students reported that they sustained an injury through sport or recreational activity within the past year that required medical attention or resulted in one day of time loss from physical activity participation. Injured participants displayed a significantly higher mean BMI z-score, had a significantly increased odds of being overweight or obese, and demonstrated longer left foot ECDB times compared to uninjured participants. No statistically significant differences were noted in waist circumference, predicted VO₂max, vertical jump height, right foot ECDB times, or normalized reach distances on the SEBT between injury groups, although the mean predicted VO₂max values and mean vertical jump heights were greater in the injured group within all strata (ages 11-13 and 14-16 in both females and males). Results from the exploratory analysis demonstrated that participants who had sustained two S&R injuries in the previous year had a significantly higher mean BMI z-score and a significantly higher mean waist circumference compared to participants with no previous injury.

6.2 Public Health Implications

Injuries sustained through sport or recreational activity account for two of every three injuries in youth,^{1,2} and pose a substantial economic burden.^{1,4} This is not surprising due to the high sport participation rates in this population, with studies reporting that 75-94% of children and youth participate in organized sport over the previous year.⁶⁻⁸ Despite these high participation rates, there has been a substantial decline in physical fitness levels and higher

overweight and obesity rates in children and youth when compared to the 1970's.^{9,10} These trends are associated with negative long term health consequences, including the development of metabolic disorders that have previously been identified as long term negative health outcomes in adults.¹³ The primary analyses from this study demonstrated associations between previous injury and BMI and between previous injury and left foot balance times. This suggests that improving body composition outcomes may require greater focus in youth who have sustained a previous injury in order to help decrease the prevalence of overweight and obesity, thus improving the economic burden imposed by consequential metabolic diseases.

Physical activity exposure may have explained the significantly better left foot balance times in the injury group, as well as the higher predicted VO₂max scores and vertical jump height (although not significant) compared to those with no previous injury. Higher levels of sport participation have been associated with increased injury, and those who participate in sport are likely to be more fit compared to those who do not participate in regular physical activity.

Despite the fact that individuals participating in sport may be at increased risk of sustaining a S&R injury, the benefits of regular physical activity outweigh the consequences of injury. It is critical to focus on injury prevention so that children and youth can continue participating in sport and obtaining the physical activity benefits including: better physical fitness levels, healthier body composition, improved physical literacy, and a decreased risk of metabolic disorders later in life.⁴⁶ Adequate physical preparation for sport participation is an important component of injury prevention, thus it is necessary to continue to promote regular physical activity participation to improve physical fitness.⁴⁰

6.3 Recommendations for Future Research

Future research is warranted to evaluate the association between previous injury and health and physical fitness outcomes, and should include prospective studies to examine temporality and control for physical activity exposure in this relationship. Longitudinal studies would be beneficial in highlighting outcomes that are affected over time. As most studies focus on recreationally active adults and elite athletic populations, it is important to evaluate how injury affects the health and physical fitness of children and adolescents. Schools are an excellent avenue for recruitment, since samples are more likely to be inclusive of participants representing a variety of demographic and socioeconomic backgrounds and athletic capacities. Preventing injuries and improving health and physical fitness outcomes in this population is also essential to prevent negative health consequences, including the high rates of overweight and obesity and low physical fitness that are demonstrated globally.⁴⁶

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APPENDIX A: SAMPLE SIZE CALCULATION

$\alpha=0.05/5=0.01$ (Divided by 5 since there are 5 main objectives)

$\beta=0.80$

Sample Size Calculation based on BMI

σ^2 =Variance=10 BMI scores

δ =Effect size=3 BMI scores

$$N = \frac{2 (z_{1-\alpha/2} + z_{1-\beta})^2 \sigma^2}{\delta^2}$$

$$N = \frac{2(2.58+0.84)^2 (10)}{3^2}$$

$N=25.99$, round up to 26 per group

Controlling for Cluster:

N^* =adjusted sample size per group

N =previously determined sample size per group (see above)

m =cluster size = 30

ρ = kappa coefficient, ICC

$$N^* = N[1+(m+1) \rho]$$

$$N^* = 26 [1+(30+1) 0.06]$$

$$N^* = 74.36 = 75 \text{ per group} \times 2 \text{ groups} = \mathbf{150 \text{ total}}$$

$$\mathbf{150/4=37.5=38 \text{ per school}}$$

Sample Size Calculation based on Waist Circumference

$$\sigma^2 = \text{Variance} = 41.25 \text{ cm}$$

*Ranges used as variance from WC data in Richmond et al. (2012).

$$\delta = \text{Effect size} = 12 \text{ cm}$$

$$N = \frac{2 (z_{1-\alpha/2} + z_{1-\beta})^2 \sigma^2}{\delta^2}$$

$$N = \frac{2 (2.58 + 0.84)^2 (41.25)}{12^2}$$

$$N = 6.70, \text{ round up to 7 per group}$$

Controlling for Cluster:

N* = adjusted sample size per group

N = previously determined sample size per school (see above)

m = cluster size = 30

ρ = kappa coefficient, ICC = 0.06

$$N^* = 7 [1 + (m+1) \rho]$$

$$N^* = 7 [1 + (30+1) 0.06]$$

$$N^* = 20 \text{ per group} \times 2 \text{ groups} = \mathbf{40 \text{ total}}$$

$$40/4 \text{ schools} = 10 \text{ per school}$$

Sample Size Calculation based on 20-m Shuttle Run scores

$$\sigma^2 = \text{Variance} = 8$$

*Mean of ranges used as variance. Calculated between 10th and 95th percentiles within males and females in the 11 year old and 15 year old age group normative data scores, Léger et al. 1982.

δ = Effect size = 2 shuttle run levels

$$N = \frac{2 (z_{1-\alpha/2} + z_{1-\beta})^2 \sigma^2}{\delta^2}$$

$$N = \frac{2 (2.58 + 0.84)^2 (8)}{2^2}$$

N = 46.78, round up to 47 per group

Controlling for Cluster:

N* = adjusted sample size per group

N = previously determined sample size per school (see above)

m = cluster size = 30

ρ = kappa coefficient, ICC = 0.06

$$N^* = N [1 + (m-1) \rho]$$

$$N^* = 47 [1 + (30-1) 0.06]$$

$$N^* = 134.42 = 135 \text{ per group} \times 2 \text{ groups} = \mathbf{270}$$

$$270 / 4 \text{ schools} = 67.5 = 68 \text{ per school}$$

Sample size calculation based on Vertical Jump scores

$$\sigma^2 = \text{Variance} = 21.5 \text{ cm}$$

*Mean of ranges used as variance. Calculated between 10th and 95th percentiles within males and females in the 11 year old and 15 year old age group normative data scores (Taylor et al., 2010).

$$\delta = \text{Effect size} = 6 \text{ cm}$$

$$N = \frac{2 (z_{1-\alpha/2} + z_{1-\beta})^2 \sigma^2}{\delta^2}$$

$$N = \frac{2 (2.58 + 0.84)^2 (21.5)}{6^2}$$

$$N = 13.97, \text{ round up to } 14 \text{ per group}$$

Controlling for Cluster:

N* = adjusted sample size per group

N = previously determined sample size per school (see above)

$$m = \text{cluster size} = 30$$

$$\rho = \text{kappa coefficient, ICC} = 0.06$$

$$N^* = N[1 + (m+1) \rho]$$

$$N^* = 14 [1 + (30+1) 0.06]$$

$$N^* = 40.04 = 41 \times 2 \text{ groups} = \mathbf{82}$$

$$82/4 \text{ schools} = 20.5 = 21 \text{ per school}$$

Sample Size Calculation based on Eyes-closed Dynamic Balance

$$\sigma^2 = \text{Variance} = 9.25 \text{ sec}$$

*Range from Richmond et al. (2012) used as variance.

$$\delta = \text{Effect size} = 2 \text{ sec}$$

$$N = \frac{2 (z_{1-\alpha/2} + z_{1-\beta})^2 \sigma^2}{\delta^2}$$

$$N = \frac{2 (2.58 + 0.84)^2 (9.25)}{2^2}$$

$$N = 54.09 \text{ round up to } 55 \text{ per group}$$

Controlling for Cluster:

N*=adjusted sample size per group

N=previously determined sample size per school (see above)

m=cluster size = 30

ρ = kappa coefficient, ICC = 0.06

$$N^* = N[1 + (m-1) \rho]$$

$$N^* = 55 [1 + (30-1) 0.06]$$

$$N^* = 157.3 = 158 \times 2 \text{ groups} = \mathbf{316}$$

$$316/4 \text{ schools} = 79 \text{ per school}$$

APPENDIX B: CONSENT AND ASSENT FORMS

CONSENT FORM

TITLE: Pilot Development and Validation of a combined obesity and sport injury prevention intervention in junior high school students.

INVESTIGATORS: Dr. Carolyn Emery, PhD, PT, Dr. Alberto Nettle-Aguire, PhD, Dr. Tish Doyle-Baker, PhD, DPH, and Sarah Richmond, MSc., PhD (Student), CEP

This consent form is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your child's participation will involve. If you would like more detail about something mentioned here, or information not included here, please ask. Take the time to read this carefully, to understand any accompanying information, and to discuss this research project with your child. You will receive a copy of this form.

BACKGROUND

The number of overweight and obese children and adolescents has increased dramatically in the past thirty years. Risk factors such as high amounts of dietary fat and sugars, sedentary activity and low physical activity are all predictors of the increase in overweight and obese youth. Of particular importance, are the implications of these changes, as obesity in youth has been shown to increase the risk of obesity in adulthood. Furthermore, overweight and obese adolescents are at an increased risk for obesity related morbidity and mortality such as cardiovascular disease, type 2 diabetes, glucose intolerance, and the metabolic syndrome.

However, in Canada, sport participation is the leading cause of injury in adolescents. There is an increasing trend in the adolescent population towards participation in organized sport. Without proper prevention strategies, adolescents are at increased risk for sport injury and therefore, may be at increased risk for decreased physical activity. As adolescent sport injury will likely reduce future involvement in physical activity, it may also impact the future health of our population.

There is a critical need for research that will lead to both obesity and injury prevention in adolescents. It is essential to develop and examine the effectiveness of a combined obesity and sport injury prevention program.

Your child's school has been selected to participate in this study. There are expected to be 700 participants in this study.

WHAT IS THE PURPOSE OF THE STUDY?

The purpose of this study is to develop and examine the effectiveness of a combined obesity and injury prevention program in junior high schools in the Calgary area. Once the intervention program has been validated, it will enable us to conduct future studies examining prevention strategies to reduce both obesity and injury in junior high schools.

WHAT WOULD MY CHILD HAVE TO DO?

At the beginning of the school year, your child will be asked to complete a baseline questionnaire. This will be reviewed with the physical education specialist in your child's school. In addition, your child will be asked to participate in a fitness assessment conducted by a Certified Exercise Physiologist (CEP) and a Physiotherapist (PT) at a physical education class.

A school representative [ie. Teacher, CEP, PT, or CAT(C)] will be asked to submit an injury report form to the PT in the event that a student experiences a sporting injury. **Any injury which occurs during a sporting activity that required medical attention, and/or resulted in the cessation of the sporting activity and/or time loss of at least one day of sporting activity is considered reportable.** If your child does seek other medical attention, it is requested that the attending medical professional (ie. physician, physiotherapist, athletic therapist, nurse, etc.) complete a medical practitioner report form. If your child experiences an injury they will be referred to the assigned CAT(C) (who will be present at one PE class each week) for assessment and follow-up recommendations. A sport medicine physician at the Sport Medicine Centre, University of Calgary, will be available for follow-up if recommended by the CAT(C). Treatment recommendations only will be made to your child in the event of an injury.

WHAT ARE THE RISKS?

There are no expected risks to participating in this study. The baseline measurements described above will be done under close supervision and every effort will be made to ensure your child's safety.

ARE THERE ANY BENEFITS FOR MY CHILD?

If you agree to participate in this study there may or may not be a direct medical benefit to your child. His/her obesity and injury risk may be decreased during the study but there is no guarantee that this research will help him/her. If your child experiences a sport injury during the study, an athletic therapist designated to your child's school will be available on a weekly basis for assessment of injuries and recommendations for follow-up treatment. The information we get from this study may help us to provide better obesity and sport injury prevention in the future in adolescent programs and sport.

DOES MY CHILD HAVE TO PARTICIPATE?

No, your child does not have to participate. If you agree to allow your child to participate, we require you to sign and return this form to your school designate. Two copies of the form have been provided. Please keep one for your records. Please have another adult witness your signature on the copy that you return to us.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in this research project and agree to allow your child to participate as a subject. In no way does this waive your legal rights nor release the investigators, sponsors, or involved institutions from their legal and professional responsibilities. Your child is free to withdraw from the study at any time. Continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your child's participation. If there is new information available through this study period, you will be informed as soon as possible.

WILL WE BE PAID FOR PARTICIPATING, OR DO WE HAVE TO PAY FOR ANYTHING?

There will be no financial compensation to the student or costs to the student as a participant in this study.

WILL MY CHILD'S RECORDS BE KEPT PRIVATE?

All of the information collected will remain strictly confidential. Your child's privacy will be assured. Only the investigators responsible for this study, the research assistant who will be doing the baseline assessments,

the data analysis and the University of Calgary Conjoint Health Research Ethics Board will have access to this information. Confidentiality will be protected by using a study identification number in the database. Any results of the study which are reported will in no way identify study participants.

IF MY CHILD SUFFERS A RESEARCH-RELATED INJURY, WILL WE BE COMPENSATED?

In the event that your child suffers an injury as a result of participating in this research, no compensation will be provided for you by the University of Calgary, the Calgary Health Region or the researchers. You still have all your legal rights. Nothing said here will in any way alter your rights to seek damages.

SIGNATURES

Your signature on this form indicates that you have understood to your satisfaction the information regarding your child's participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the investigators, or involved institutions from their legal and professional responsibilities. Your child is free to withdraw from the study at any time without jeopardizing your health care.

Parent/Guardian's Name

Signature and Date

Child's Name

Signature and Date

Investigator/Delegate's Name

Signature and Date

Witness' Name

Signature and Date

The University of Calgary Conjoint Health Research Ethics Board has approved this research study.

A signed copy of this consent form has been given to you to keep for your records and reference.

**PARENT/GUARDIAN
CONSENT FORM**

TITLE: Evaluation of the effectiveness of neuromuscular training in decreasing the risk of sport and recreational injuries and improving healthy outcomes in junior high school students (iSPRINT)

SPONSOR: Alberta Innovates Health Solutions - Collaborative Research and Innovation Opportunities (AIHS-CRIO)

INVESTIGATORS: Dr. Carolyn Emery, PhD, PT, Dr. Tish Doyle-Baker, PhD, DPH, and Sarah Richmond, MSc., PhD, CEP

This consent form is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your child's participation will involve. If you would like more detail about something mentioned here, or information not included here, please ask. Take the time to read this carefully, to understand any accompanying information, and to discuss this research project with your child.

BACKGROUND

The health of children and adolescents has decreased dramatically in the past thirty years. Poor nutritional choices and declining levels of physical activity are major contributors to this decrease in health in youth. These individuals are at increased risk for chronic disease, obesity during adulthood, and pose a greater economical burden on our healthcare system.

Although it is important to include physical activity in our daily life in order to help maintain an overall healthy lifestyle, it is still important to note that there are injury risks involved, particularly when participating in sport. As Canadians are encouraged to increase their physical activity, it is important to focus on proper injury prevention strategies, especially in children and youth. An adolescent sport injury will likely reduce future involvement in physical activity, and may also impact their future health.

Neuromuscular training programs have been found to be effective in reducing injury risk in adolescents when they are applied in a sport-specific scenario. A previous randomized control trial, using only two schools, has also found this intervention, along with a high intensity exercise component, to be effective in reducing injuries and improving healthy outcomes when incorporated into a junior high school physical education curriculum as a standardized warm-up delivered by teachers.

The current study will be the same as the previous school study, and will include more participants and schools. Your child's school has been selected to participate in this study. There are expected to be 1940 participants in this study.

WHAT IS THE PURPOSE OF THE STUDY?

The purpose of this study is to examine the effectiveness of an injury prevention program in junior high schools in the Calgary area. This intervention has been previously delivered to two junior high schools in Calgary, and was effective in decreasing injury risk and improving healthy outcomes. A larger number of students are now needed in order to evaluate the effectiveness of this program on a larger scale in Alberta's physical education curriculum.

Over the next three years, 12 junior high schools from Calgary will be randomized to receive either the intervention program or a control program, which will include standard warm-up exercises. If your child's school is randomized into the control group, they will be able to receive the intervention program the following year.

WHAT WOULD MY CHILD HAVE TO DO?

An information package has been provided to you via your child, that includes this consent form, a child assent form, a baseline questionnaire (which includes demographic information, physical activity participation, and injury history), the PAR-Q and You, a

Knowledge and Behavioral Questionnaire and the EQ-5D-Y, which is a quality of life questionnaire. If you decide to consent to your child's participation, you and your child will be required to complete these forms and return them to the PE teacher before they are collected by the research coordinator. In addition, your child will be asked to participate in a fitness assessment conducted by kinesiology graduates and a Certified Exercise Physiologist (CEP) during a physical education class. Measurements will include height, weight, waist circumference, 20 metre shuttle run (also known as the beep test), vertical jump test, and balance assessments.

In the event your child sustains an injury from any type of physical activity (i.e. PE class, sport participation or training, recreational activity etc.), they will be required to report it to a school representative. The school representative will be asked to submit an injury report form to the study therapist (certified athletic therapist) who will visit the school each week to assess any new injuries. If your child does seek other medical attention, it is requested that the attending medical professional (i.e. physician, physiotherapist, athletic therapist, nurse, etc.) complete a medical practitioner report form, which will be available from the school representative. If your child experiences an injury they will be referred to the assigned therapist for assessment and follow-up recommendations at school. Referral to a sport medicine physician, at the University of Calgary will be offered and arranged by the study therapist for all suspected concussions.

WHAT ARE THE RISKS?

There are no expected risks to participating in this study. The baseline measurements described above will be done under close supervision and every effort will be made to ensure your child's safety.

ARE THERE ANY BENEFITS FOR MY CHILD?

If you agree for your child to participate in this study there may or may not be a direct medical benefit to your child. His/her health and injury risk may be improved during the study but there is no guarantee that this research will help him/her. If your child experiences an injury from physical activity participation during the study, a study therapist designated to your child's school will be available on a weekly basis for assessment of injuries and recommendations for follow-up treatment. The information we get from this study may help us to provide better programs to improve health and physical activity injury prevention in the future among adolescents.

DOES MY CHILD HAVE TO PARTICIPATE?

No, your child does not have to participate. If you agree to allow your child to participate, we require you to sign and return this form to your school designate. Please have another adult witness your signature on the copy that you return to us. If you would like a copy of this form for your personal records, it can be downloaded from our website www.ucalgary.ca/siprc or you can call the Research Coordinator and ask for a copy to be sent to your address.

Your child is free to withdraw from the study at any time. Continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your child's participation. If there is new information available through this study period, you will be informed as soon as possible. We will contact you prior to the 2015 and 2016 school year to see if you are willing to allow your child continued participation in this study, if they are currently in Grade 7 and 8.

Please note that you or your child (if over 18 years of age) may be contacted in the future for invitation to participate in other research studies that may relate to any injuries that your child may sustain within the duration of this study.

WILL WE BE PAID FOR PARTICIPATING, OR DO WE HAVE TO PAY FOR ANYTHING?

There will be no financial compensation to the student or costs to the student as a participant in this study.

WILL MY CHILD'S RECORDS BE KEPT PRIVATE?

All of the information collected will remain strictly confidential. Your child's privacy will be assured. Only the investigators responsible for this study, the research assistant who will be doing the baseline assessments and the data analysis, and the University of Calgary Conjoint Health Research Ethics Board will have access to this information. Confidentiality will be protected by using a study identification number in the database. Any results of the study which are reported will in no way identify study participants.

IF MY CHILD SUFFERS A RESEARCH-RELATED INJURY, WILL WE BE COMPENSATED?

In the event that your child suffers an injury as a result of participating in this research, no compensation will be provided for you by the University of Calgary, Alberta Innovates Health Solutions, the Alberta Health Services, or the researchers. You still have all your legal rights. Nothing said here will in any way alter your rights to seek damages.

SIGNATURES

Your signature on this form indicates that you have understood to your satisfaction the information regarding your child's participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the investigators, or involved institutions from their legal and professional responsibilities. Your child is free to withdraw from the study at any time without jeopardizing your health care.

If you have any questions concerning your rights as a possible participant in this research, or research in general, please contact the Chair of the Conjoint Health Research Ethics Board, University of Calgary, at 403-220-7990.

_____ Parent/Guardian Name (Please Print)	_____ Signature	_____ Date

_____ Parent Email	_____ Parent Home Phone	_____ Parent Alternative Phone

_____ Child's Name (Please Print)	_____ Signature	_____ Date

_____ Child's School	_____ Child's Grade (7, 8 or 9)

_____ Witness Name (Please Print)	_____ Signature	_____ Date

Office use only

_____ Research Staff	_____ Signature	_____ Date

The University of Calgary Conjoint Health Research Ethics Board has approved this research study.

**CHILD
ASSENT FORM**

PROJECT TITLE: Evaluation of the effectiveness of neuromuscular training in decreasing the risk of sport and recreational injuries and improving healthy outcomes in junior high school students (ISPRINT study)

PRINCIPLE INVESTIGATORS: Dr. Carolyn Emery, PhD, PT, Dr. Tish Doyle-Baker, PhD, DPH, and Sarah Richmond, MSc., PhD, CEP

WHAT IS A RESEARCH STUDY?

A research study is a way to find out new information about something. You do not need to be in a research study if you don't want to.

WHY ARE YOU BEING ASKED TO BE PART OF THIS RESEARCH STUDY?

You are being asked to take part in this research study because we are trying to learn more about injury risks in adolescents. We are asking you to be in the study because your school has been chosen to participate in a study looking at neuromuscular training program as a part of physical education class, and we want to find out if you are less likely to be injured if you participate in this program. About 1940 junior high school students will be in this study from Calgary.

IF YOU WANT TO JOIN THE STUDY, WHAT WILL HAPPEN TO YOU?

We want to tell you about some of the things that will happen to you if you are in this study.

- You will be in this study for at least 6 months, but if you are still in junior high in 2015, 2016 or 2017, you might be in the study for 2 or 3 years. We will check with your parents at the start of every school year to see if you are happy to stay in the study.
- You will fill out some questionnaires at the beginning of the study, which will ask questions about your medical background, your participation in physical activity and your injury history, what you know about preventing injuries, and if you have any challenges in your daily life. All of these questionnaires have been included in this package.
- You will participate in some testing where a group of researchers will take your height, weight, and measure your waist as well as run you through some fitness measurements at the beginning of the study during PE class.
- You will participate in a specific warm-up program at the start of your physical education class that will be taught by your teacher(s).
- You will report any injuries you get during PE class, from playing any sport during or out-of-school, or from any recreational physical activity, to your teacher or to the researchers.

WILL ANY PART OF THE STUDY HURT?

This study will not hurt you. The activities you do in this study will not be very different from the ones that you participate in during your physical education classes.

WILL THE STUDY HELP YOU?

If you agree to participate in this study, there may or may not be benefits for you. The study may decrease your risk for injury or improve your health, but there is no guarantee that this will happen. If you do get injured, a physiotherapist or certified athletic therapist will be available to assess your injuries and give you recommendations for treatment.

WILL THE STUDY HELP OTHERS?

The information that we get from this study may help us to provide more programs that may prevent injury and improve the health of adolescents in the future.

DO YOUR PARENTS KNOW ABOUT THE STUDY?

We have also provided a consent form for your parents to read that will let them know about this study. You can talk this over with them before you decide.

WHO WILL SEE THE INFORMATION COLLECTED ABOUT YOU?

The information collected about you during this study will be kept safely locked up. Nobody will know about it except for the people doing the research. The study information about you will not be given to your parents. The researchers will not tell your friends, your school or anyone else.

WHAT DO YOU GET FROM BEING IN THIS STUDY?

You do not have to pay for anything to be in this study. You will not receive anything for participating in this study.

DO YOU HAVE TO BE IN THE STUDY?

No, you do not have to be in this study. No one will be upset if you don't want to do this study. If you don't want to be in this study, you just have to tell us. It's up to you.

WHAT IF YOU HAVE ANY QUESTIONS?

You can ask any questions that you may have about the study. If you have a question later that you didn't think of now, either you can call or have your parents call the Research Coordinator

You can also take more time to think about being in the study and also talk some more with your parents about being in the study.

WHAT CHOICES DO YOU HAVE IF YOU SAY NO TO THIS STUDY?

This study is extra, so if you don't want to do it, nothing else will change.

OTHER INFORMATION ABOUT THIS STUDY:

If you decide to be in the study, please write your name below. You can change your mind and stop being part of it at any time. All you have to do is tell the person in charge. The researchers and your parents won't be upset. You can download a copy of this paper to keep from our website <http://www.ucalgary.ca/siprc>

Would you like to take part in this study? (Please ✓ one)

_____ Yes, I will be in this research study.

_____ No, I don't want to do this.

_____
Child's full name (Print clearly)

_____
Signature of the child

_____
Date

_____
School name

_____
Grade (7, 8 or 9)

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_____
Research Staff

_____
Signature

_____
Date

Ethics ID REB14-0470, Dr Carolyn Emery

iSPRINT study

v2 7 Oct 2014

APPENDIX C: PAR-Q+ FORM

PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

Regular physical activity is fun and healthy, and more people should become more physically active every day of the week. Being more physically active is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

SECTION 1 - GENERAL HEALTH

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.		YES	NO
1.	Has your doctor ever said that you have a heart condition OR high blood pressure?	☐	☐
2.	Do you feel pain in your chest at rest, during your daily activities of living, OR when you do physical activity?	☐	☐
3.	Do you lose balance because of dizziness OR have you lost consciousness in the last 12 months? Please answer NO if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4.	Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)?	☐	☐
5.	Are you currently taking prescribed medications for a chronic medical condition?	☐	☐
6.	Do you have a bone or joint problem that could be made worse by becoming more physically active? Please answer NO if you had a joint problem in the past, but it does not limit your current ability to be physically active. For example, knee, ankle, shoulder or other.	☐	☐
7.	Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.

Go to Section 3 to sign the form. You do not need to complete Section 2.

- › Start becoming much more physically active – start slowly and build up gradually.
- › Follow the Canadian Physical Activity Guidelines for your age (www.csep.ca/guidelines).
- › You may take part in a health and fitness appraisal.
- › If you have any further questions, contact a qualified exercise professional such as a CSEP Certified Exercise Physiologist* (CSEP-CEP) or CSEP Certified Personal Trainer* (CSEP-CPT).
- › If you are over the age of 45 yrs. and NOT accustomed to regular vigorous physical activity, please consult a qualified exercise professional (CSEP-CEP) before engaging in maximal effort exercise.

If you answered YES to one or more of the questions above, please GO TO SECTION 2.

Delay becoming more active if:

- › You are not feeling well because of a temporary illness such as a cold or fever – wait until you feel better
- › You are pregnant – talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the PARmed-X for Pregnancy before becoming more physically active OR
- › Your health changes – please answer the questions on Section 2 of this document and/or talk to your doctor or qualified exercise professional (CSEP-CEP or CSEP-CPT) before continuing with any physical activity programme.

SECTION 2 - CHRONIC MEDICAL CONDITIONS

Please read the questions below carefully and answer each one honestly: check YES or NO.		YES	NO
1.	Do you have Arthritis, Osteoporosis, or Back Problems?	☐ If yes, answer questions 1a-1c	☐ If no, go to question 2
1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	☐	☐
1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	☐	☐
2.	Do you have Cancer of any kind?	☐ If yes, answer questions 2a-2b	☐ If no, go to question 3
2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and neck?	☐	☐
2b.	Are you currently receiving cancer therapy (such as chemotherapy or radiotherapy)?	☐	☐
3.	Do you have Heart Disease or Cardiovascular Disease? This includes Coronary Artery Disease, High Blood Pressure, Heart Failure, Diagnosed Abnormality of Heart Rhythm	☐ If yes, answer questions 3a-3e	☐ If no, go to question 4
3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
3b.	Do you have an irregular heart beat that requires medical management? (e.g. atrial fibrillation, premature ventricular contraction)	☐	☐
3c.	Do you have chronic heart failure?	☐	☐
3d.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer YES if you do not know your resting blood pressure)	☐	☐
3e.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	☐	☐
4.	Do you have any Metabolic Conditions? This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes	☐ If yes, answer questions 4a-4c	☐ If no, go to question 5
4a.	Is your blood sugar often above 13.0 mmol/L? (Answer YES if you are not sure)	☐	☐
4b.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, and the sensation in your toes and feet?	☐	☐
4c.	Do you have other metabolic conditions (such as thyroid disorders, pregnancy-related diabetes, chronic kidney disease, liver problems)?	☐	☐
5.	Do you have any Mental Health Problems or Learning Difficulties? This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome)	☐ If yes, answer questions 5a-5b	☐ If no, go to question 6
5a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
5b.	Do you also have back problems affecting nerves or muscles?	☐	☐

Please read the questions below carefully and answer each one honestly: check YES or NO.		YES	NO
6.	Do you have a Respiratory Disease? This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure	☐ If yes, answer questions 6a-6d	☐ If no, go to question 7
6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
6b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	☐	☐
6c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	☐	☐
6d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	☐	☐
7.	Do you have a Spinal Cord Injury? This includes Tetraplegia and Paraplegia	☐ If yes, answer questions 7a-7c	☐ If no, go to question 8
7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
7b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	☐	☐
7c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	☐	☐
8.	Have you had a Stroke? This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event	☐ If yes, answer questions 8a-c	☐ If no, go to question 9
8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
8b.	Do you have any impairment in walking or mobility?	☐	☐
8c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	☐	☐
9.	Do you have any other medical condition not listed above or do you live with two chronic conditions?	☐ If yes, answer questions 9a-c	☐ If no, read the advice on page 4
9a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months OR have you had a diagnosed concussion within the last 12 months?	☐	☐
9b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	☐	☐
9c.	Do you currently live with two chronic conditions?	☐	☐

Please proceed to Page 4 for recommendations for your current medical condition and sign this document.

PAR-Q+

If you answered NO to all of the follow-up questions about your medical condition, you are ready to become more physically active:

- › It is advised that you consult a qualified exercise professional (e.g., a CSEP-CEP or CSEP-CPT) to help you develop a safe and effective physical activity plan to meet your health needs.
- › You are encouraged to start slowly and build up gradually – 20-60 min. of low- to moderate-intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- › As you progress, you should aim to accumulate 150 minutes or more of moderate-intensity physical activity per week.
- › If you are over the age of 45 yrs. and NOT accustomed to regular vigorous physical activity, please consult a qualified exercise professional (CSEP-CEP) before engaging in maximal effort exercise.

If you answered YES to one or more of the follow-up questions about your medical condition:

- › You should seek further information from a licensed health care professional before becoming more physically active or engaging in a fitness appraisal and/or visit a or qualified exercise professional (CSEP-CEP) for further information.

Delay becoming more active if:

- › You are not feeling well because of a temporary illness such as a cold or fever – wait until you feel better
- › You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the PARmed-X for Pregnancy before becoming more physically active OR
- › Your health changes - please talk to your doctor or qualified exercise professional (CSEP-CEP) before continuing with any physical activity programme.

SECTION 3 - DECLARATION

- › You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- › The Canadian Society for Exercise Physiology, the PAR-Q+ Collaboration, and their agents assume no liability for persons who undertake physical activity. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.
- › If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.
- › Please read and sign the declaration below:

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that a Trustee (such as my employer, community/fitness centre, health care provider, or other designate) may retain a copy of this form for their records. In these instances, the Trustee will be required to adhere to local, national, and international guidelines regarding the storage of personal health information ensuring that they maintain the privacy of the information and do not misuse or wrongfully disclose such information.

NAME _____ DATE _____

SIGNATURE _____ WITNESS _____

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER _____

For more information, please contact:
Canadian Society for Exercise Physiology
www.csep.ca

KEY REFERENCES

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2. Warburton DER, Gledhill N, Jamnik VK, Bredin SSD, McKenzie DC, Stone J, Charlesworth S, and Shephard RJ. Evidence-based risk assessment and recommendations for physical activity clearance; Consensus Document. APNM 36(S1):S266-S298, 2011.

The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or BC Ministry of Health Services.

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APPENDIX D: BASELINE QUESTIONNAIRE

Study Subject ID#

(to be completed by study coordinator):

OBESITY and INJURY PREVENTION 2008-2009

Baseline Questionnaire: GIRLS

Name:		Today's Date:			
☐ Male ☐ Female		_____ Day _____ Month _____ Year			
Age:	Grade:	Phone #: ( ) -			
Height: _____ feet _____ inches or _____ cms		Date of Birth:			
Weight: _____ (lbs)		_____ Day _____ Month _____ Year			
Have you started to menstruate (ie. started your periods)? ☐ Yes ☐ No					
Are your periods regular (ie. approximately 1X/month)? ☐ Yes ☐ No					
At what age did you begin to menstruate? _____ Years _____ Months					
MEDICAL/INJURY HISTORY:					
1. Have you ever had a concussion or been "knocked out" or had your "bell rung"? ☐ Yes ☐ No <i>if yes, please list:</i>					
Date:	Activity at the time	Time unconscious		Memory loss (yes or no)	Time loss before FULL return to sport
<i>eg. (DD/MM/YY)</i>	<i>hockey, skateboarding, etc.</i>	<i>0min</i>	<i>30sec</i>	<i>no</i>	<i>1 day, 10 days, etc</i>
b) If you answered yes to Question 1, please indicate whether you have any persistent problems with:					
a) memory		☐ Yes ☐ No			
b) dizziness		☐ Yes ☐ No			
c) headaches		☐ Yes ☐ No			

questionnaire continues (over) -

Baseline Questionnaire Page 2
OBESITY and INJURY PREVENTION 2008-2009

2. In the past **6 weeks** have you had an injury requiring medical attention and at least one day of time lost from physical activity? ☐ Yes ☐ No

If **yes**, please describe this injury or these injuries to the best of your ability:

Injury Date	Injury Type	Body Part	Sport of Occurrence	Treatment description	Estimated time loss from sport (days/wks)
<i>eg. (DD/MM/YY)</i>	<i>sprain, bruise, etc.</i>	<i>knee, nose, etc.</i>	<i>soccer, wakeboarding, etc.</i>	<i>first aid, physio, etc.</i>	<i>1 day, 3 weeks, etc</i>

3. In the past **one year**, have you had any other injury requiring medical attention & at least one day of time lost from physical activity? ☐ Yes ☐ No

If **yes**, please describe this injury or these injuries to the best of your ability:

Injury Date	Injury Type	Body Part	Sport of Occurrence	Treatment description	Estimated time loss from sport (days/wks)

4. Do you have any incompletely healed injury? ☐ Yes ☐ No

If **yes**, describe this injury to the best of your ability:

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5. Have you been diagnosed by a physician with a bone fracture, arthritis, systemic disease (ie. cancer, heart disease), neurological disorder (ie. head injury, cerebral palsy) or have you required surgery in the past year?

☐ Yes ☐ No

If **yes**, describe this condition(s) to the best of your ability:

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6. In the past **6 weeks**, how many weeks and how many hours per week (on average) did you participate in a school PE class?

_____ number of weeks _____ hours per week

7. Based on the past **6 weeks** of activity, did you participate in any sports on a weekly basis (**NOT including PE class**)?

☐ Yes ☐ No

If **yes**, please estimate the average number of hours per week you participated in each sport:

SPORT	hrs/week	SPORT	hrs/week	SPORT	hrs/week
Aerobics		Floor hockey		Skateboarding	
Alpine skiing		Football		Snowboarding	
Badminton		Golf		Soccer	
Baseball		Gymnastics		Squash	
Basketball		Hiking/ Scrambling		Speed skating	
Boxing (incl. kick)		Hockey		Swimming	
Cross-country skiing		Horse riding		Tennis	
Cycling (road or mtn)		Lacrosse		Track and field	
Dance		Martial arts		Volleyball	
Dirt biking		Rock climbing		Waterpolo	
Diving		Rollerblading		Weight training	
Field hockey		Rugby		Wrestling	
Figure skating		Running		*Other:	
				*Please describe:	

Section 1: Demographics

Full Name:		Sex: ☐ Male ☐ Female	Today's Date: ____ Day ____ Month ____ Year	
Age:	Grade:		Phone (Home) _____ Number (Cell) _____	
Date of Birth: ____ Day ____ Month ____ Year		Height: ____ feet ____ inches or ____ cm		Weight: ____ lbs or ____ kgs
Home address (including postal code):				
What is the highest level of education completed by each of your parents or guardians?				
☐ Junior High or less		☐ Junior High or less		
☐ High School Diploma		☐ High School Diploma		
☐ Technical or Trade Certificate		☐ Technical or Trade Certificate		
☐ Undergraduate Degree		☐ Undergraduate Degree		
☐ Postgraduate Degree or higher		☐ Postgraduate Degree or higher		
FEMALES ONLY: Complete the next 4 questions				
Have you started to menstruate? (i.e., started your period)		☐ Yes ☐ No → go to Section 2		
Are your periods regular? (i.e., approximately once a month)		☐ Yes ☐ No ☐ Don't Know		
On average, how many periods do you have per year?		☐ 0-3 ☐ 4-6 ☐ 7-9 ☐ 10+		
At what age did you begin to menstruate?		____ Years ____ Months		

Section 2: Organized Sport & Recreational Activity Participation in the Past 6 Weeks & Past Year

2a. Based on the past **6 weeks** of activity, did you participate in any sports or recreational activities, NOT including PE class?

(Example: a formal school or community team, OR community club, OR recreation centre where fees are paid and training OR competition is held at least weekly. E.g., community hockey, an aerobics class, swim club, community gym, etc.)

☐ Yes ☐ No → go to 2b

If **yes**, please estimate the average number of hours per week you participated in each sport or recreational activity, in the past 6 weeks:

Sport/ Recreational Activity	hrs. per wk	Sport/ Recreational Activity	hrs. per wk	Sport/ Recreational Activity	hrs. per wk
Aerobics		Floor hockey		Skate/longboarding	
Alpine skiing		Football		Snowboarding	
Badminton		Golf		Soccer	
Baseball		Gymnastics		Squash	
Basketball		Hiking/Scrambling		Speed skating	
Boxing (incl. kick)		Hockey		Swimming	
Cross-country skiing		Horse riding		Tennis	
Cycling (road or mtn.)		Lacrosse		Track and field	
Dance		Martial arts		Volleyball	
Dirt biking		Rock climbing		Water polo	
Diving		Rollerblading		Weight training	
Field hockey		Rugby		Wrestling	
Figure skating		Running		Other*:	
				*Please describe sport or recreational activity:	

2b. Based on the past **12 months** of activity, did you participate in any sports or recreational activities, NOT including PE class? Please include any activities indicated in 2a above.

(Example: a formal school or community team, OR community club, OR recreation centre where fees are paid and training OR competition is held at least weekly. E.g., community hockey, an aerobics class, swim club, community gym, etc.)

☐ Yes ☐ No → go to Section 3

If **yes**, please estimate the number of weeks and average hours per week (over the weeks you indicated) you participated in each sport or recreational activity over the past 12 months:

Sport/ Recreational Activity	no. of wks	hrs. per wk	Sport/ Recreational Activity	no. of wks	hrs. per wk	Sport/ Recreational Activity	no. of wks	hrs. per wk
Aerobics			Floor hockey			Skate/longboarding		
Alpine skiing			Football			Snowboarding		
Badminton			Golf			Soccer		
Baseball			Gymnastics			Squash		
Basketball			Hiking/Scrambling			Speed skating		
Boxing (incl. kick)			Hockey			Swimming		
Cross-country skiing			Horse riding			Tennis		
Cycling (road or mtn.)			Lacrosse			Track and field		
Dance			Martial arts			Volleyball		
Dirt biking			Rock climbing			Water polo		
Diving			Rollerblading			Weight training		
Field hockey			Rugby			Wrestling		
Figure skating			Running			Other*:		
						*Please describe sport or recreational activity:		

Section 3: Active Transportation

3. In a typical week, which of the following modes of transportation do you use between home and school? (Check all that apply)

3a. Travelling from Home to School		
Check	Mode of transportation	Average hrs per wk
☐	Car	
☐	Bus	
☐	Walk	
☐	Cycle	
☐	Train	
☐	Other (please specify):	

3a. Travelling from School to Home		
Check	Mode of transportation	Average hrs per wk
☐	Car	
☐	Bus	
☐	Walk	
☐	Cycle	
☐	Train	
☐	Other (please specify):	

3c. In a typical week, which of the following modes of transportation do you use to get to and from places other than school? (Check all that apply)

(Example: a friend's house, sport practice, errands, etc.)

Check	Mode of transportation	Average hrs per wk
☐	Car	
☐	Bus	
☐	Walk	
☐	Cycle	
☐	Train	
☐	Other (please specify):	

Section 4: Physical Activity During School Hours

4a. In the past 6 weeks , how many weeks did you participate in school PE class? _____		
4b. In a typical week, how many physical education classes (gym classes) do you participate in? _____		
4c. Are you currently fully participating in physical education class? ☐ Yes ☐ No		
4d. In your typical physical education class, what percent of time do you spend in:		
Light intensity physical activity (Breathing is normal & you are <u>not</u> working hard enough to break into a sweat) <i>Example: casual walking, stretching, putting away equipment</i>	Moderate intensity physical activity (Breathing slightly harder than normal & working hard enough to break into a light sweat) <i>Example: brisk walking, yoga, gymnastics, recreational swimming, volleyball, badminton</i>	Vigorous intensity physical activity (Breathing hard & fast & working so hard that you are sweating heavily) <i>Example: jumping rope, soccer, football, basketball, swimming laps, karate</i>
☐ less than 25% of the time	☐ less than 25% of the time	☐ less than 25% of the time
☐ 25-50% of the time	☐ 25-50% of the time	☐ 25-50% of the time
☐ 51-75% of the time	☐ 51-75% of the time	☐ 51-75% of the time
☐ 76-100% of the time	☐ 76-100% of the time	☐ 76-100% of the time
4e. Other than during your physical education class, how many additional hours per week do you participate in physical activity during school hours? <i>(Example: at lunch break, during other class time)</i>		
Light intensity physical activity (Breathing is normal & you are <u>not</u> working hard enough to break into a sweat) _____hrs/wk	Moderate intensity physical activity (Breathing slightly harder than normal & working hard enough to break into a light sweat) _____hrs/wk	Vigorous intensity physical activity (Breathing hard & fast & working so hard that you are sweating heavily) _____hrs/wk

Section 5: Leisure-Time Physical Activity Outside of School Hours

5a. In a typical week (including weekends), how many times, on average, do you do the following kinds of exercise for **more than 15 minutes** during your free time?

*This does not include physical activity that you recorded in sections 2-4 (i.e., excludes organized sport/recreational activities, active transport, and physical activity during school hours).

Activity type	Average times per week	Average minutes per session
Mild (Breathing is normal & you are <u>not</u> working hard enough to break into a sweat) <i>e.g., archery, bowling, horseshoes, golf, easy walking.</i>		
Moderate (Breathing slightly harder than normal & working hard enough to break into a light sweat) <i>e.g., fast walking, baseball, tennis, easy bicycling, volleyball, badminton, easy swimming, alpine skiing, non-competitive popular dancing, yoga.</i>		
Vigorous (Breathing hard & fast & working so hard that you are sweating heavily) <i>e.g., running, jogging, hockey, football, soccer, squash, basketball, cross country skiing, judo, roller skating, swimming, running.</i>		

5b. In a typical week (including weekends), in your leisure time, how often do you engage in regular physical activity where **you are breathing hard & fast** OR **working so hard that you are sweating heavily**?

☐ Often ☐ Sometimes ☐ Never

Section 6: Medical/Injury History

6a. Have you ever had a concussion or been "knocked out" or had your "bell rung"?

☐ Yes ☐ No ☐ Don't Know

If **yes**, please list for each occurrence:

Injury Date <i>dd/mm/yy</i>	Activity at the time <i>(e.g., skiing, hockey, school yard fight)</i>	Time unconscious		Memory loss <i>(yes or no)</i>	Number of days before FULL return to physical activity <i>(e.g., 3 weeks)</i>	Was the concussion diagnosed by a doctor? <i>(yes or no)</i>
		minutes	seconds			

If you answered **yes** to 6a), please indicate whether you have any persistent problems with:

i) Memory ☐ Yes ☐ No
 ii) Dizziness ☐ Yes ☐ No
 iii) Headaches ☐ Yes ☐ No

6b. In the past **12 months**, have you had any other injuries requiring medical attention OR at least one day where you couldn't participate in physical activity?

☐ Yes ☐ No

If **yes**, please describe this injury or these injuries to the best of your ability:

Injury Date <i>dd/mm/yy</i>	Injury Type <i>e.g., sprain, bruise</i>	Body Part <i>e.g., knee, nose</i>	Activity of Occurrence <i>e.g., soccer, wakeboarding</i>	Treatment description <i>e.g., first aid, physio</i>	Estimated missed days from physical activity <i>e.g., 13 days</i>

6c. Do you have any incompletely healed injuries? i.e., an injury that has not 100% healed/recovered.

☐ Yes ☐ No

If **yes**, please describe this injury to the best of your ability:

6d. Are you currently receiving treatment for this injury/these injuries?

☐ Yes ☐ No

If **yes**, please describe the treatment you are receiving:

6e. Do you take any medications (e.g., asthma inhaler, Advil, Tylenol, etc.) on a regular basis?

☐ Yes ☐ No

If **yes**, please describe the medications you are taking:

6f. Are you currently taking any supplements (e.g., vitamins, minerals, protein powder etc.)?

☐ Yes ☐ No

If **yes**, please describe the supplements you are taking:

6g. Have you been diagnosed by a physician with a bone fracture, arthritis, or any other bone related condition?

☐ Yes   ☐ No   ☐ Don't Know

If **yes**, what was the year of diagnosis? _____

Please describe the condition/s to the best of your ability:

6h. Have you been diagnosed by a physician with asthma or some other respiratory conditions (e.g., chronic respiratory failure, congenital lung abnormalities)?

☐ Yes   ☐ No   ☐ Don't Know

If **yes**, what was the year of diagnosis? _____

Please describe the condition/s to the best of your ability:

6i. Have you been diagnosed by a physician with a systemic disease (e.g., cancer, thyroid disease, heart disease)?

☐ Yes   ☐ No   ☐ Don't Know

If **yes**, what was the year of diagnosis? _____

Please describe the condition/s to the best of your ability:

6j. Have you ever been diagnosed by a physician with a circulation or heart-related problem (e.g., heart murmur, irregular heart beat, congenital deformity of the heart)?

☐ Yes   ☐ No   ☐ Don't Know

If **yes**, what was the year of diagnosis? _____

Please describe the condition/s to the best of your ability:

6k. Have you been diagnosed by a physician with a neurological disorder (e.g., brain injury, cerebral palsy, pinched nerve, "stinger", multiple sclerosis, etc.)?

☐ Yes   ☐ No   ☐ Don't Know

If **yes**, what was the year of diagnosis? _____

Please describe the condition/s to the best of your ability:

6l. Have you ever experienced headaches?

☐ Yes   ☐ No   ☐ Don't Know

If **yes**, are they associated with (please check all that apply):

- ☐ Nausea
- ☐ Vomiting
- ☐ Sensitivity to Light
- ☐ Sensitivity to Noise

6m. Does anyone else in your family experience headaches?

☐ Yes   ☐ No   ☐ Don't Know

If **yes**, please list which family members? _____

6n. Have you ever been concerned that you have an attention or learning issue?

☐ Yes   ☐ No   ☐ Don't Know

If **yes**, please describe to the best of your ability? _____

6o. Have you ever been formally diagnosed by a health care professional (physician, psychologist, etc.) with any of the following: (check all that apply)

☐ Cognitive Delay	☐ Oppositional Defiant Disorder
☐ Communication Disorder	☐ Conduct Disorder
☐ Pervasive Developmental Disorder	☐ Mood Disorder
☐ ADHD	☐ Depression
☐ Learning Disability	☐ Bi-Polar
☐ Anxiety Disorder	☐ Developmental Coordination Disorder
☐ Disruptive Behavior Disorder	☐ Other: _____

Section 7: Health Care Utilization

7a. Please indicate whether or not you visited the following practitioners or received the following services for **any reason in the past 12 months** (exclude visits and services received as an inpatient in a hospital).

Practitioners and Services	Visited	Number of Visits	No Visits
physician - emergency room doctor	☐		☐
physician - general practitioner/ family	☐		☐
physician - sport medicine doctor	☐		☐
surgeon	☐		☐
physiotherapist	☐		☐
chiropractor	☐		☐
massage therapist	☐		☐
athletic therapist	☐		☐
magnetic resonance imaging (MRI)	☐		☐
computer tomography (CT scan)	☐		☐
radiographs (x-rays)	☐		☐
other (please specify) _____	☐		☐

7b. In the past year, have you been admitted to the hospital for any reason, including emergency department visits?

☐ Yes (please continue below)   ☐ No (questionnaire completed!)

7c. Please describe ANY hospitalizations (including emergency department visits) you had in the **past year**, below. If you had more than 3 hospital visits, use a separate sheet to describe.

Primary reason for hospital visit	Number of nights in hospital or ED visit	Did you have surgery while in the hospital?	
		I DID NOT have surgery	I DID have surgery: Please name and describe the surgery to best of your ability.
		☐	
		☐	
		☐	

Thank you for your time in completing this questionnaire. Please return this form to your teacher with the signed consent and assent form and the PAR-Q form