THE COMPOSITION OF A CHILD'S PHYSICAL ACTIVITY AND THEIR CARDIO-METABOLIC HEALTH

By

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A thesis submitted to the School of Kinesiology and Health Studies
in conformity with the requirements for
the degree of Masters of Science

Queen’s University
Kingston, Ontario, Canada
(September, 2017)

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Abstract

**Purpose:** The purposes of this study of 10-13 year old children were to: (1) determine if time spent in different domains of physical activity was independently associated with selected cardio-metabolic risk factors, and (2) estimate whether replacing time in one domain of physical activity with time in another domain of physical activity was associated with changes in cardio-metabolic risk factors.

**Methods:** 385 children aged 10-13 years were studied. Participants wore a Garmin Forerunner 220 GPS watch, an Actical accelerometer, and completed an activity log for 7 consecutive days during the school year. Data from these measures was used to estimate average minutes/day spent in active transportation, outdoor active play, organized sport, and curriculum-based physical activity at school. Percent body fat, resting heart rate, and systolic blood pressure were measured using automated equipment. Isotemporal substitution regression models were used to estimate changes in cardio-metabolic risk factors that occurred when time spent in each domain of physical activity was replaced with an equivalent amount of time in another domain.

**Results:** After adjusting for covariates, outdoor active play was associated with body fat % (β = -.058, 95% CI = -.095, -.021) and organized sport was associated with resting heart rate (β = -.040, 95% CI = -.071, -.009). In the isotemporal substitution models, replacing 10 minutes/day of organized sport with outdoor active play was favourably associated with body fat % (β = -.048, 95% CI = -.094 to -.002) and replacing 10 minutes/day of active transportation with organized sport was favourably associated with resting heart rate (β = -.109, 95% CI = -.197, -.020).
Conclusion: These findings suggest that replacing time spent in organized sport with an equal amount of time in active play may have beneficial effects on body fat and that replacing time spent in active transportation with an equal time in organized sport may improve resting heart rate. No significant effects were observed when curriculum-based physical activity was replaced by another domain of activity.
Co-Authorship

This thesis presents the work of Anne Macgregor in collaboration with her supervisor, Dr. Ian Janssen. The data used in this thesis are from the Active Play Study, for which Ms. Chao Xue was the coordinator and Dr. Janssen was the primary investigator. The conceptualization of this thesis was a collaborative effort between Anne Macgregor and Dr. Janssen.

Anne Macgregor performed the literature review, statistical analyses, interpretation of results, and writing of the thesis chapters. Dr. Janssen provided ongoing technical and general guidance and edited the thesis.
Acknowledgements

First and foremost, I would like to thank my supervisor Dr. Ian Janssen. It was through your guidance and expertise that I was able to experience an overwhelmingly positive yet challenging graduate school experience. The skills that I have acquired as a researcher, writer, and student, over the past 2 years will no doubt continue to serve me well throughout my professional career. Most importantly, I would like to thank you for your unyielding patience and thoughtful feedback throughout my thesis project which ensured that it was completed to the best of my abilities.

I would also like to thank each of my lab mates; without whom this project would not have been possible. Mike, Laura, Rob, Andrew, Gillian, Yingyi, Emily, and Chao, thank you for contributing to a constantly inspiring, hardworking, and enjoyable work environment. Without your positive attitudes, inclination to help others, and enthusiasm, my Master’s thesis and the Active Play Study wouldn’t be what it is today. In particular, I would like to acknowledge Mike. Thank you for your guidance, your willingness to teach, and your friendship throughout these past years.

Thank you to my incredible friends Andrea, Emily, Devon, Victoria, Sarah, Celine, Aleksandra, and Madison, for their unconditional friendship and encouragement, and for each day bringing a smile to my face. To my family, thank you for continuing to inspire me, support me, and push me to be the best version of myself. I am fortunate to have you behind me every step of the way.

Lastly, thank you to Dr. Ian Janssen, Queen’s University, and the Heart and Stroke Foundation of Canada for their financial support which funded this thesis.
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List of Abbreviations

LIPA – Light Intensity Physical Activity
MVPA – Moderate to Vigorous Physical Activity
CI – Confidence Interval
PA – Physical activity
BMI – Body Mass Index
WC – Waist Circumference
HR – Heart Rate
SBP – Systolic Blood Pressure
SES – Socio-Economic Status
DPA – Daily Physical Activity
Chapter 1

Introduction

1.1 General Overview

The importance of physical activity in a young person’s life is well documented (1) and indicates that more active children and adolescents have a healthier physical (2) and mental (3) health. For instance, regular physical activity of any intensity is associated with lower blood pressure and body weight (1,4–6). Unfortunately, the physical activity levels of Canadian children and adolescents have declined in recent decades and only 9% meet public health guidelines for physical activity on a daily basis (1,7). These guidelines recommend that children accumulate at least 60 minutes per day of moderate-to-vigorous physical activity (MVPA) (7).

Exercise scientists often characterize physical activity according to the FITT principles, which refer to the Frequency, Intensity, Time (duration), and Type of the activity. The relationship between the frequency, intensity, and duration of physical activity and health within children has been well studied and forms the basis of the evidence used to establish the public health guidelines for physical activity (1,7–11). There is also evidence that the type of activity influences health. The type of activity is often classified according to whether it is aerobic- or resistance-based, and aerobic-based activities have a greater impact on several health outcomes than do resistance-based activities (11,12). Another way to classify the type of activity is according to the domain in which it is performed. Within children and adolescents these domains are organized sports and programs, active transportation, curriculum-based physical activity and other organized school activities, and active play (13).

Existing literature has not examined whether the cardio-metabolic health benefits are different for the different physical activity domains. It is possible that time spent in one physical
activity domain does not influence health to the same degree as an equivalent amount of time spent in another physical activity domain because the intensity of movement differs across the different domains (1,7–12) and because some but not all physical activity domains are associated with increased exposure to nature and the outdoors. Several studies have demonstrated that physical activities which contain more minutes of MVPA result in more favorable cardio-metabolic profiles (6,14–17). Additionally, exposure to nature and the outdoors may decrease cortisol levels in the blood (18), which in turn can have a favorable impact on blood pressure and body weight (19).

It is important to consider whether the health benefits are different for the different physical activity domains because children and adolescents can only devote a set amount of time to physical activity per day, and because compensation between physical activity domains may occur (20–22). Compensation would occur if an increase amount of time devoted to one domain would result in a decrease in time devoted to one or more of the other domains. For example, it is conceivable that if a child participates in a 60-minute hockey practice in the evening, this would replace the time the child would have otherwise spent playing outdoors.

1.2 Scientific Significance

The amount of time children engage in physical activity is an important determinant of health (23). A lack of time is an often cited barrier to physical activity (24), only a finite amount of time within a child’s day can be spent engaging in physical activity, and time spent in one domain of physical activity may displace time spent in another domain (25). Research is needed to determine if altering the relative contribution of the physical activity domains to the overall time spent in physical activity as this may provide an avenue for benefiting a young person’s health if the time devoted to physical activity cannot be increased.
1.3 Objectives and Hypothesis

The objectives of this thesis research were to: 1) determine if time spent in each physical activity domain is independently associated with selected cardio-metabolic risk factors, and 2) estimate whether replacing time spent in each domain with an equivalent amount of time spent in the other domains is associated with changes in cardio-metabolic risk. It is hypothesized that time spent in each physical activity domain will be independently associated with the cardio-metabolic risk factors, and that the greatest health benefits will be observed when replacing the time spent in curriculum-based physical activity with equal time in active play.

1.4 Thesis Organization

This thesis follows the guidelines specified by the Queen’s University School of Graduate Studies “General Form of Theses” as well as the guidelines of the School of Kinesiology and Health Studies for a manuscript-based thesis. The enclosed thesis consists of 4 chapters. Chapter 1 provides an overview of the topic, a rational for the thesis, as well as the objectives. Chapter 2 provides a critical review of the literature examining the relationships between the physical activity domains and health within children and adolescents. The third chapter is the Manuscript. The research completed for the manuscript analyzes the association between the composition of 10-13 year old’s physical activity and their cardio-metabolic health. Chapter 4 provides a general discussion which highlights key findings, public health implications, as well as strengths and weaknesses of the current research. Additional details of the methodology of this thesis, including detailed research protocols and ethics approval, are presented as appendices.

1.5 References:


Chapter 2

Literature Review

2.1 Outline

This chapter consists of a literature review that discusses how the different domains of children’s and adolescent’s physical activity influences their cardio-metabolic health. The review begins by defining the key term and concepts used in this thesis. This is followed by sections which describe the influence that the individual domains of physical activity have on cardio-metabolic health. Next, the literature review considers whether the associations between physical activity and cardio-metabolic health could differ across the physical activity domains and the mechanistic pathways that could explain such differences. The ensuing section describes the idea of time limitations, displacement and compensation in physical activity. Finally, a summary of limitations and the gaps in current literature is provided.

2.2 Definitions of Key Terms and Concepts

Biologically, a child as any person who is between birth and puberty (1). For the purposes of this study, a child is any person between the ages of 5 and 11. Pre-adolescence is defined as the stage of human development preceding puberty and it occurs at approximately the ages of 11 and 12 (1). Adolescence follows the onset of puberty, typically between the ages 12 and 17 (1). This thesis research focuses on pre and early adolescence (ages 10-13); however, the literature review includes studies of school-aged children and adolescents ranging from 5 to 17 years of age. This age range was chosen as 10 year old children would be independent enough to responsibly use the physical activity measurement devices and accurately complete the log and, at 13, young enough to frequently participate in outdoor active play.
Physical activity refers to any bodily movement produced by skeletal muscles that results in energy expenditure (2). Physical activity is often characterized using the FITT principles (i.e., frequency, intensity, time, type). Frequency refers to how often a person performs a physical activity over a particular period of time, such as a day or week. Intensity is often measured using metabolic equivalents (METs) where one MET is equivalent to 1 kcal expended for each kg of body weight per hour (3). This measurement allows for the categorization of physical activity intensity as light (1.6 – 2.9 METs), moderate (3.0 – 5.9 METs), or vigorous (≥ 6.0 METs) (4). Moderate and vigorous physical activity intensities are usually combined as moderate to vigorous physical activity (MVPA). Time refers to the length or duration of physical activity. Time is often considered in terms of the length of a specific bout of physical activity (e.g., a 30 minute walk) or the total duration of all bouts of physical activity performed over a day or week. The type of activity is often classified according to whether it is aerobic- or resistance-based (e.g. swimming versus weight lifting) (5,6). The type of physical activity can also be characterized by the domain in which it is accumulated. In children these domains primarily consist of organized spots and programs, active transportation, curriculum-based physical activity, and active play.

Organized sports and programs refers to physical activities that are typically structured by rules, are often competitive, and are usually supervised by an adult such as a referee or coach (7). Examples include a soccer game, basketball practice, or gymnastics lesson. Active transportation refers to transportation that is self-propelled and includes activities such as walking and cycling to school or other destinations (8). Curriculum-based physical activity refers to activities done during class-time at school such as physical education class (7) or daily physical activity (DPA) (9). Physical education is a class taught in school that focuses on motor skill development in a movement setting (7). DPA is part of regular school curriculum in some Canadian provinces and
focuses on accumulating minutes of MVPA rather than motor skill development (9). Finally, *active play* refers to activities that are highly unstructured, typically freely chosen and led by children, and are often performed with minimal or no adult supervision (10). Examples include playing house, playing on playground structures, and climbing trees. This thesis will focus on active play performed outdoors.

*Cardio-metabolic risk* describes a condition in which the possibility of developing atherosclerotic cardio-vascular disease and type 2 diabetes mellitus is significantly increased (11). As these diseases are typically developed in adulthood, pediatric research studies examine cardio-metabolic risk factors that are known predictors of future cardio-metabolic disease. These risk factors include adiposity measures, measures of insulin and glucose metabolism, blood lipids and lipoproteins, and blood pressure (11–14). It is important to study these cardio-metabolic risk factors in the early years as both preventing risk factor development and understanding key steps to modify these risk factors once they are established could help prevent the onset of cardio-metabolic diseases in the future (15).

### 2.3 Physical Activity Levels in Children and Adolescents

According to the most recent surveillance data from Statistics Canada, only 9% of 5 to 17 year olds in Canada are meeting the physical activity recommendation that is part of the 24-Hour Movement Guidelines for Children and Youth (16). This percentage has remained roughly stable since 2009, when only 7% of children in this age group were meeting the recommendation (17). The low prevalence for total physical activity could reflect that children and youth are not spending enough time in one or more of the individual physical activity domains.

Approximately 76% of 11-15 year old Canadians participate in at least one form of organized sport (16). It is unclear, however, how much time per day children and adolescents
participate in these sports and their contribution to daily minutes of MVPA. Roughly 37% of children and adolescents participate in >2 hour/day of active outdoor play outside of school hours increasing their daily minutes of MVPA (16). These results, however, were based off of self-report and could be biased. Active transportation is the domain with the least amount of participation among children with a mere 26% of 11-15 year olds using active modes of transportation (24% walking, 2% cycling) on their way to/from school each day (16). All Canadian schools offer opportunities for physical activity through physical education and/or DPA (16), and roughly 80% of students are enrolled in these programs.

2.4 Physical Activity and Health in Children

Exercise scientists often characterize physical activity according to the FITT principles, which refer to the Frequency, Intensity, Time (duration), and Type of the activity, as previously define and described. The relationship between the frequency, intensity, and duration of physical activity and health within children and adolescents has been well studied and forms the basis of the evidence used to establish 24-Hour Movement Behaviour Guidelines for Children and Youth (5,8,17–20). These guidelines recommend that young people between the ages of 5 and 17 accumulate a minimum of 60 minutes per day of MVPA involving a variety of aerobic activities (16). These should include vigorous-intensity physical activities three days per week, and activities which strengthen muscle and bone tissue three days per week (16). The guidelines also highlight the importance of light physical activity and recommend that children accumulate several hours of light physical activity each day (16). The physical activity recommendations within the new Canadian 24-hour Movement Behaviour Guidelines for Children and Youth were based upon a series of systematic reviews that examined how physical activity influences a variety of physical, mental, and social health outcomes (16).
The frequency, or patterns, in which physical activity is performed is also of importance to a young person’s cardio-metabolic health. Children not only accumulate daily minutes of MVPA in different patterns (i.e. >5 min bouts vs <5 sporadic minutes) but also accumulate their weekly MVPA in different ways (i.e. ≥60 minutes on 1–4 days/week vs. 5–7 days/week) (21,22).

A cross-sectional study investigating the way in which MVPA was accumulated (bouts vs sporadically in equivalent volumes) found that cardio-metabolic risk decreased almost identically for both patterns (22). Another cross-sectional study investigated the different patterns in which children accumulated their weekly MVPA and their cardio-metabolic risk. It was found that children and adolescents (age 6-19) who accumulated 60 min/day of MVPA on average per day but only met this target <5 days/week were more insulin resistant than children who accumulated >60 min/day of MVPA on average over 7 days (21). From these findings, it appears as though it is more beneficial for a child/adolescent’s cardio-metabolic health to accumulate 7 hours of weekly MVPA over 7 days than over 4 days (21). This study also indicated that children who accumulate MVPA in this pattern or frequency, may be more likely to accumulate higher levels of activity throughout the week (21).

An extensive body of evidence has shown that activities with more minutes of MVPA are associated with favourable markers of cardio-vascular and cardio-metabolic health such as healthier insulin levels, waist circumference, cholesterol levels, and blood pressure (23,24,14,25,26). Light intensity physical activity (LIPA) has not been as strongly or consistently related to cardio-metabolic risk factors as MVPA (14).

The duration, or average time per day, for which a child participates in physical activity is of crucial importance to their cardio-metabolic health. Though an optimal duration is very
difficult to define, dose-response patterns suggest that there is a curvilinear association between MVPA duration and cardio-metabolic health. Current Canadian guidelines indicate that children and youth should accumulate at least 60 min/day of MVPA from a variety of aerobic activities (16). These guidelines were supported through a cross-sectional study involving 1170 youth aged 8-17 which examined the dose-response relationship between objectively measured physical activity, blood pressure, and hypertension (27). The results indicated that children and youth who met these guidelines were approximately 2 thirds less likely to develop hypertension as compared to children who did not participate in any MVPA (27). Conversely, a more recent study examining the dose-response relationship between MVPA and dyslipidemia in adolescents (n = 1235, aged 12-19), observed that there were reductions in the likelihood of elevated risk factors for atherosclerosis with even fewer minutes per day of MVPA than recommended by the guidelines (28). This was further supported by a systematic review which indicated that participation in as little as 2 or 3 hours of MVPA/week is associated with health benefits (29). These studies indicate a strong curvilinear dose-response relationship between minutes of MVPA and cardio-metabolic risk, and though an optimal dose of MVPA is not possible to define, it is clear that with more minutes of MVPA, additional benefits are attained.

There is also evidence that the type of physical activity influences health. The type of activity is often classified according to whether it is aerobic- or resistance-based. Aerobic exercise consists mainly of repetitive large muscle group movements such as cycling and running (30). Resistance training, which refers to exercise undertaken against an external workload, typically in a circuit format involving many different muscle groups, generally provides a larger gain in skeletal muscle mass than aerobic training. Aerobic-based activities
have a greater impact on several health outcomes, such as blood pressure and blood lipids, than do resistance-based activities, which have been found to aid in bone strengthening (5,6).

Many intervention studies have investigated the cardio-metabolic benefits of either aerobic or resistance based exercise. A study which investigated aerobic exercise alone found that, compared with the control group, exercising children had decreased body fat % (-2.2%), total fat mass (-3.1%), subcutaneous abdominal tissue (-16.1%), and increased fat free mass (31). Conversely, a 5-month intervention study which investigated resistance exercise alone indicated that, following the intervention, total body weight had significantly increased in both the control and intervention group, and though fat-free mass increased in the exercise group (27.1 to 29.2kg), visceral fat mass, subcutaneous adipose tissue and total body fat % increased as well (32). Though these results indicate that resistance training may not impact cardio-metabolic health to the same degree as aerobic training (30,32), one intervention study which investigated the impact of resistance based exercise vs aerobic exercise on obesity measures in adolescents (n = 55, 12-19 years old) contradicted these results (33). Results indicated that, compared to controls, significant reductions in body weight (aerobic: 20.04 ± 0.8 kg; resistance: 20.6 ± 0.8 kg), total (aerobic: -2.6±0.6 p = 0.002, resistance: -2.5±0.6 p = 0.004) and visceral adiposity (aerobic: -0.1±0.04 p<0.0001, resistance: -0.2±0.04 p<0.0001) were observed in both exercise groups (33). Interestingly, only resistance exercise was seen to improve insulin sensitivity (33). This was further investigated by two systematic reviews which examined whether a combination of both types of exercise or one type alone has a greater influence on a child and adolescent’s cardio-metabolic health. One study found that obesity and cardio-metabolic health measures responded almost exclusively to aerobic interventions which stress the cardio-vascular and respiratory systems, and therefore suggested that these types of activities should be focused on
Another study, however, found that long term concurrent exercise interventions provided greater benefits to cardio-metabolic health than simply aerobic activity in obese children and adolescents (35). From the above-mentioned studies it is clear that further research must be done to investigate the influence of aerobic vs. resistance training on a child and adolescent’s cardio-metabolic health.

The domain of activity may also influence cardio-metabolic health. As the intensity of movement differs across the different domains, and because the intensity of movement influences health, it is possible that there are differences in the way which the domains influence health (20).

2.5 Outdoor Active Play and Cardio-Metabolic Health

Active play, particularly when performed outdoors, can be an important component of a young person’s total physical activity. An Australian study observed that each additional hour spent in outdoor active play was associated with 27 additional minutes of MVPA among a sample of 306 girls aged 10-12 years (36). Additionally, there is evidence that 9-17 year olds who play outdoors most or all of the time after school have a 2.84 times greater odds of achieving the recommended amount of MVPA and that they accumulate 70 minutes/day less sedentary time compared to children who spend little or no time playing outdoors, independent of season, weight status, and sex (37).

Only a few studies have examined the association between the active play domain of physical activity or outdoor time (a proxy of outdoor play) and cardio-metabolic risk factors. These few studies have focused on obesity measures. Within a cross-sectional study of 360 preadolescents, each additional hour/day spent in outdoor active play was associated with a decreased prevalence of overweight (36). This was especially evident in participants who spent ≥
3 hours/day playing outdoors, whose likelihood of being overweight was reduced by approximately 30% by comparison to those spending <2 hours/day playing outdoors (Boys: RR = 0.7, 95% CI: 0.56-0.87, Girls: RR = 0.7 CI: 0.49-0.98) (36). The results from this study, however, were based off of self-report over a 7 day period (including weekends) and could be subject to recall bias. Additionally, an American study conducted within a large cohort (n=3861) of 3 to 16-year-olds observed that time spent outdoors was associated with a lower odds of increasing BMI z-score over a two year follow-up (OR = 0.87, 95% CI= 0.79-0.97) (38). In contrast to these findings, Schaefer et al. reported that there was no association between outdoor time and BMI z-score among 9-17 year olds; however, these authors did find that participants who spent most of their afterschool time outdoors had higher cardiorespiratory fitness, which is an important modifiable risk factor for several cardio-metabolic health outcomes (37).

There are limitations with the three studies discussed above. Two of the three were cross-sectional (36,38). Additionally, one of them used outdoor time as an indicator of outdoor play (37). This is a key limitation as not all time spent outdoor is spent in play. Lastly, all three of these studies used self-reported measures of active play or outdoor time, and as such are susceptible to recall bias. Such bias could have either increased or decreased the observed association, depending on whether the bias resulted in differential or non-differential misclassification of the physical activity measures.

2.6 Organized Sports / Programs and Cardio-Metabolic Health

Organized sports and programs can make a significant contribution to a child and adolescent’s total daily physical activity (39–42). One American study examined this association through self-report and determined that 20% of an adolescent’s daily physical activity energy expenditure is expended through this physical activity domain (39). Another
study examined this relationship by measuring total MVPA using accelerometers and found that 6-12 year old boys who participated in organized sport accumulated 30 additional minutes of MVPA on the days they participated in sports as compared to boys that did not participate in organized sport (40). This was further demonstrated by a Portuguese study which indicated that 12 to 18 year olds who participated in an organized sport were at a 6.57 greater odds of meeting MVPA guidelines by comparison to those who did not participate (42).

The literature regarding the associations between participation in organized sports and programs with cardio-metabolic risk factors lacks consensus. Three cross-sectional studies have examined the association between sport participation and obesity measures. Silva et al. showed that the higher daily MVPA achieved through extracurricular sport did not translate to a more favourable BMI among a group of 208 adolescents aged 12 to 18 years (42). Contradictorily, Romani et al., who studied 1400 pre and early adolescent boys and girls in two separate studies, found that participation in an organized sport was associated with a more favourable BMI in a dose-response manner (43,44). Specifically, they reported that the BMI was 2.1% lower within boy and girls who participated in organized sports and that their likelihood of being overweight and obese were reduced by 8.2% and 3.1%, respectively.

The discrepancy across the aforementioned studies could have been caused by the methods used to evaluate organized sport. The study that did not find an association between organized sport participation and BMI asked participants to recall one week of activity, and this one week of activity may not have accurately reflected habitual sport participation (42). Conversely, the papers that found significant associations between organized sport and BMI asked participants to recall a year’s worth of sport participation, and this would have better reflected their typical participation (42–44).
A Finnish longitudinal study aimed to understand the association between participation in organized sport during childhood and adolescence (ages 3, 6, 9, 12, 15, and 18) and changes in cardio-metabolic risk factors over the course of 21 years (45). Their results showed that persistent participation in organized sport as a child and adolescent was significantly and inversely associated with more beneficial changes in adiposity, blood pressure, and insulin, as compared to non-athletes. This was demonstrated with a large effect size (d = 0.97 for males, d = 0.89 for females) (45). Possible explanations for this finding are that sustained participation in sport during childhood and adolescence leads to improved cardio-vascular function and physical fitness that carries over into adulthood, or that athletic children and adolescents are more inclined to practice health-related habits such as avoiding unhealthy diets, smoking, and sedentary lifestyles – all of which have been found in increase the risk for metabolic syndrome (45). As sport participation was only assessed using a self-report questionnaire, it is possible that some athletes changed from one type of sport to another, or that they took time off from sport within the 21-year follow up period.

Results based on self-reported measures of organized sport frequency suggest that sustained participation in organized sport has a beneficial effect on a child’s total physical activity, BMI, and other cardio-metabolic risk factors. Research regarding the associations between the time spent participating in organized sport (and not just yes/no to participating) and cardio-metabolic health is warranted, and this line of research would benefit from using objective measures of physical activity.

2.7 Active Transportation and Cardio-metabolic Health

Active transportation, such as walking, cycling, or skateboarding, may offer a convenient way to increase a young person’s daily physical activity (8). One small study (n= 219) of 10-11
year olds in grade 5 noted that preadolescents who cycled or walked to and/or from school accumulated approximately 24 additional minutes/day of MVPA on school days as compared to passive commuters (46). This study, however, under-represented students from low socio-economic status (SES) areas and therefore may not accurately represent the commuting patterns of all 5th grade students. Additionally, the study had a low recruitment rate (36.6%), indicating a possible selection bias (46). Another study reported slightly less robust results with active school commuters accumulating an extra 8.4 minutes (95% CI = 3.7-13.1) of MVPA per day (47) as compared to passive commuters. This study, however, was only completed with girls and may not be generalizable to boys.

The results from intervention studies are not as strong as those from the observational studies discussed above. For instance, a “walking school bus” intervention, wherein a group of 9 year old children walked to and from school along a set route with adult supervision (48), indicated that children who participated in the intervention accumulated only 2 additional minutes in MVPA daily (46.6 ± 4.5 pre-intervention vs. 48.8 ± 4.5 post-intervention) (48). This suggests that active transportation interventions, or at least those that focus solely on active transportation to school, may not be as effective at increasing MVPA as previously believed. A possible explanation for the discrepancy between the intervention studies and observational studies could be due to the distance the participants lived from their schools. In the observational studies no restriction was placed on this distance, whereas in the “walking school bus” intervention study the children had to live within 1-mile of their school. It is therefore conceivable that children in the observational studies lived much further from school and accumulated more minutes of MVPA as they were simply walking a further distance. Additionally, it is plausible that the active commuters in the observational studies were also, on
average, more active in other domains, and accumulated on average more daily minutes of MVPA as compared to passive commuters.

It is unclear if active transportation to school influences cardio-metabolic risk factors. A 10 week “walking school bus” intervention study was completed with a small sample (n=28) of 5-11 year olds living within one mile of their school. Though 76% of students participated in the intervention trial at least 3 times per week, it was found that there were no statistical differences in changes in BMI z-score between the active transportation intervention group and the passive transportation control group (49). It could be reasoned that the length of this intervention was not sufficient to elicit any body composition changes. Contrarily, results from a Danish cross-sectional study investigating the associations between active transportation and BMI among adolescents (aged 12-16 years old ) concluded that cycling to and from school is associated with lower BMI (50,51). Cycling to school, among 12-14 year olds, was associated with -0.55 lower BMI ($P < 0.001$) when compared to passive transportation for the same age group. Furthermore, the authors found that walking and cycling to school were associated with 0.47 and 0.63 lower relative odds, respectively, of being overweight when compared to passive travellers (51). One study examined the association between active transportation to school with BMI and triceps skinfold thickness among 1107 9-10 year olds. Children were categorized as active travellers if they participated $\geq$3x/week, and as passive travellers if they participated less than three times per week. The study concluded that, at baseline, male active travellers had significantly lower measures (BMI: active = 17.25, non-active = 18.01, $p < 0.05$ 0.01; skinfolds (mm): active = 24.62, non-active 27.33, $p < 0.05$) (8). This result, however, was not persistent over the course of a two year follow-up possibly due to the manner in which active transportation was categorized.
This could suggest that a low frequency of active commuting (i.e. <3x/week) may not be sufficient to elicit changes in body composition.

A major gap of the active transportation research is the focus on obesity measures, such as BMI, and on active transportation to school. Other cardio-metabolic risk factors (i.e. blood pressure, blood lipid content) and total active transportation has not been considered. Another major limitation of this research, at least for the observation studies, was the use of self-reported data that could have led to misclassification of active transportation behaviours.

2.8 Curriculum-Based Physical Activity and Cardio-metabolic Health

Schools have long been the main societal institution for the development of motor skills and the provision of physical activity for children and adolescents through physical education class (7,52). Studies have demonstrated that children and adolescents who regularly participate in physical education class have fewer discipline problems, greater attentiveness, and have a more favourable cardio-metabolic and bone health (52). Research, however, has also demonstrated that children and adolescents spend the majority of their physical education class or DPA sedentary while listening to instruction or watching other students participate (52,53). Additionally, many teachers have inadequate specialist training in physical activity and feel limited in their ability to provide lessons that are developmentally suitable and appropriately challenging (53). As such, the effectiveness of this domain of physical activity at improving cardio-metabolic heath is questionable.

A study of almost 1000 American students investigated whether increasing physical education instruction time by 1 hour/week from kindergarten to grade 2 influenced students’ BMI values. They found a small 0.3-point reduction in BMI in girls who were overweight (54). This reduction was not seen in boys or non-overweight girls (54). Similarly, a European study
investigated whether adding an additional 1 hour/week of physical education lesson to the regular curriculum over a 4 year period impacted cardio-metabolic risk factors among a group of 366 preadolescents (55). The results indicated that the average level of weight loss between the two groups never reached significance throughout the follow-up (55).

Ontario, Alberta, and British Columbia have attempted to increase children’s MVPA at school outside of physical education class through DPA. Stone et al. explored the physical activity levels of a large sample (n=1027) of 10-12 year olds during DPA programs and showed that only 19% of them achieved one ≥5 minute bout of MVPA during 20 minutes of DPA (9). Though DPA did not effectively increase daily MVPA for the 81% of participants, those who did achieve one ≥5 minute bout of MVPA accumulated significantly more MVPA during the rest of the week, had lower BMI scores, and were less likely to be classified as overweight or obese (9). Thus, if DPA were implemented more effectively, it is possible that it would have a greater impact on overall physical activity levels and health than it currently does. As this study was cross-sectional, the determination of causality is not possible and therefore warrants investigation through a longitudinal study.

These findings indicate that increasing a child’s total daily MVPA during school hours with the goal of decreasing cardio-metabolic risk factors may be valuable, though programs such as DPA could benefit from increased child participation. It is therefore important to understand the true impact of curriculum mandated physical education and physical activity programs on a child’s physical health.

**2.9 Differences across Physical Activity Domains**

While studies have examined the association between specific domains of physical activity and health, as discussed above in sections 2.5-2.8, to my knowledge the associations
have not been compared across domains. Thus, it is unknown whether time spent in one domain has a greater or smaller influence on health than time spent in the other domains. For instance, are the health benefits of 30 minutes/day of active transportation greater, smaller, or comparable to the health benefits of 30 minutes/day of organized sport, curriculum-based physical activity, or outdoor active play? This is a key gap in the literature and in large measure forms the rationale for this thesis research.

The next few paragraphs discuss some of the mechanistic pathways by which physical activity influences health and considers whether these pathways are activated to a lesser extent within some domains of physical activity than within others. The presence of such differences would provide a theoretical basis and justification for the need to directly compare the health benefits of time spent in the different physical activity domains.

One pathway by which physical activity influences health is by increasing energy expenditure. If time is held constant, energy expenditure is a function of the intensity of the activity. Several studies have demonstrated that physical activities that include more minutes of higher intensity activity result in more favourable cardio-vascular fitness and obesity measures (14,23–26). For example, a cross-sectional study involving 780 Scandinavian children, found that >40 min/day of vigorous, but not moderate, physical activity was significantly associated with a lower body fat (23). LIPA is not as strongly or consistently related to cardio-metabolic risk factors as MVPA, as demonstrated by a Canadian cross sectional study (14). This study, which involved 605 children and youth aged 9-17 years, found that students in the highest tertile of vigorous physical activity compared to those in the lowest tertile, displayed lower BMI-z (0.2 vs. 0.7, P<0.001) and waist circumference (68cm vs. 73cm, P<0.001). No significant
associations were made between these cardio-metabolic risk factors and light or moderate physical activity (14).

The health impact of physical activity intensity is an important factor to consider since there is evidence that the intensity of movement varies across the physical activity domains. Studies wherein children wore accelerometers during several different organized sports indicated that, on average, while participating in organized sport 33% of the time is spent being sedentary, 35% at LIPA, and 32% at MVPA. For outdoor active play, estimates suggest that 54% of the time is spend sedentary, 19% at a light intensity, and 27% at MVPA (3). During a physical education class, 74% of the time is spend sedentary, 14% at a light intensity, and only 12% at MVPA (3). For active transportation, which is more of a continuous activity with little variation in intensity, the average walking speed for children is in the moderate intensity range (3). Given the different intensity patterns of the different physical activity domains and the influence of the intensity of movement on health, it is possible that an equivalent amount of time spent in a given domain will have a different influence on health than an equivalent amount of time spent in a different domain.

Physical activity can influence health through pathways that are unrelated to the frequency, intensity, time, and type (FITT) of the activity. One such pathway is being exposed to nature and the outdoors while participating in physical activity. Exposure to nature and the outdoors is a universal feature of outdoor active play and active transportation. It is less common with organized sports, physical education, and DPA as these activities often occur indoors. In 2010, Statistics Canada reported that 7 of the top 10 most practiced sports among children and adolescents occurred primarily indoors (soccer, ice hockey, basketball, volleyball, figure skating, swimming, karate) and that only 3 occurred primarily outdoors (soccer, baseball, downhill
skiing). Additionally, the opportunity for outdoor physical education not only hindered by the climate, but also the availability of outdoor facilities, with only 65% of schools providing outdoor facilities which meet the needs of the students (16).

Studies have suggested that the association between outdoor active play and lower mental stress may be due to a parasympathetic response to natural, green environments (56). A parasympathetic response decreases cortisol levels in the blood, which in turn can have a favourable impact on blood pressure and body weight (57). Being outdoors also influences vitamin D levels via sunlight exposure. Low serum concentrations of vitamin D have been significantly associated with obesity, increased waist circumference, high blood pressure, and metabolic syndrome among adolescents, as well as an increased risk for cardio-vascular disease in adulthood (58), independent of physical activity level. While the exact mechanism for each of these associations remains unknown, it has been suggested that low vitamin D concentrations cause an increase in parathyroid hormone concentrations leading to increased lipogenesis and weight gain (58).

In summary, there is evidence to suggest that the intensity of physical activity differs across the different physical activity domains and that intensity of physical activity is an important determinant of health. There is also evidence that exposure to nature and the outdoors, which is a salient feature of outdoor play and active transportation and less common for the other domains, influences health through pathways that are independent of the FITT principles. Taken together these findings suggest the cardio-metabolic health benefits of time spent in one domain of physical activity may differ from the health benefits of an equivalent amount of time spent in another domain.
2.10 Physical Activity Displacement and Competing Time Interests

As a finite amount of time each day can be dedicated to physical activity, it is conceivable that time spent in one domain of physical activity could displace time spent in one or more of the other domains. For example, it is plausible that if a child has a 60-minute hockey practice in the evening, it would displace time the child would have otherwise spent playing outdoors. It is also plausible that after a soccer practice, the child would be less willing to participate in active outdoor play, and instead would increase their sedentary time. This is known as the physical activity displacement hypothesis and suggests that one domain of physical activity could replace another due to time constraints or exhaustion. This may be detrimental as not all domains influence cardio-metabolic health to the same degree and as time spent in one domain may increase time spent sedentary at a later time. (59). This was demonstrated by two recent studies in which children compensated for an increase in MVPA by later increasing their sedentary behaviour or light activity to the extent that total daily physical activity was not affected (60,61). This compensation was examined by contrasting children who used active and passive forms of transportation to school. It was found that children who used active forms of transportation to school had similar total daily energy expenditure as those who used passive forms. This suggests that active transporters decreased their physical activity during the remainder of the day as compared to the passive transporters (60,61).

The physical activity displacement hypothesis, however, is not consistent throughout the literature. In fact, one study which aimed to identify behaviours that showed evidence of activity compensation (i.e. participation in physical activity is related to decreased activity at other times) or activity synergy (i.e. participation in physical activity is related to increases in activity at other times) showed that time spent in curriculum-based physical activity, active transportation, and
organized sport, independently predicted higher total daily MVPA, largely through outdoor active play (62). Thus, there was no evidence of activity compensation. These findings were consistent with two large studies. The first (n = 6916) indicated that each additional minute of MVPA was associated 1.85 fewer minutes of inactivity on the same day (95% CI: -1.89, -1.82) (59). The second, a 4-week cardio-vascular training program for 10-11 year old boys, saw an increase in daily energy expenditure outside of the training program (63). This supports the idea that there is not a compensatory increase in inactivity with an increase in physical activity (63).

In addition to considering activity compensation from an energy expenditure perspective, one should also consider activity compensation (or displacement) from a time perspective. Time is limited to 24-hours per day and there are several competing interests for a child’s time, both at school and outside of school. At school, educators must devote time within the ~7.5-hour long school day to a variety of curriculum areas (math, science, writing, art, etc.), as well as nutrition breaks, and time devoted to these activities often take precedence over time devoted to physical education, DPA, and recess. Outside of school, children and adolescents must dedicate time to sleep, eating, homework, chores, personal care needs, etc. There is increasing evidence that young people lead highly scheduled lives and have little free time (64). A “lack of time” for physical activity is an often cited barrier to participating in more physical activity. Even during free, unscheduled time children and adolescents often believe that this time should be spent on social and family activities, or personal time (64).

Because a lack of time is a common barrier to performing more physical activity, and because there are a large number of competing interests that often take precedence over physical activity, time spend in one domain of physical activity could displace time spent in another domain of physical activity. Therefore, it is important that the limited time devoted to physical
activity be spent efficiently. A potential strategy for being efficient with the limited time spent that can be spent in physical activity is to alter the composition of the physical activity domains. That is, replace time spent in one domain with an equal amount of time spent in another domain that has a greater influence on health.

2.11 Statistical Approaches that could be Used to Determine if the Composition of Physical Activity Influences Health

Although studies have not compared the health benefits of the different physical activity domains, studies have done so for different physical activity intensities. The statistical approaches used in these studies, which are discussed in this section, could inform that statistical approaches used in future studies looking at the different physical activity domains.

2.11.1 Multivariable Regression Models

The process of including different movement intensities as predictor variables in the same regression model is the primary method researchers have used to estimate whether different physical activity intensities are associated with health outcomes independent of the other intensities. An example of this approach would be to include time spent in MVPA and time spent in sedentary behaviour as independent variables in a regression model with a cardio-metabolic risk factor as the dependent variable. If this regression approach were applied to the different physical activity domains, a basic assumption that would be made is that different physical activity domains are truly independent of each other (e.g., an increase in time spent in organized sport would have no bearing on time spent in the other physical activity domains). The physical activity displacement theory suggests that this assumption may not hold true. Another issue with this regression approach is that it is based on Euclidean geometry and space, and therefore assumes that the time that could be devoted to physical activity is infinite, which is untrue as
time is constrained (i.e., there are 24-hours in a day) and only a proportion of this time can be devoted to physical activity since children must spend time sleeping, eating, sitting at school, doing homework, etc.

2.11.2 Combined Associations of Physical Activity

Another approach that has been commonly used when examining the associations between different physical activity intensities and health outcomes is to categorize each intensity dichotomously (low vs. high) based on adherence to some standard, such as meeting the MVPA and sedentary behaviour (SB) guidelines, and to look at combinations of these categories (5,65–71). An example of this would be to dichotomize MVPA and SB and then to form the following four groups: low MVPA/high SB group, low MVPA/low SB group, high MVPA/high SB group, and high MVPA/low SB. Cardio-metabolic risk factors can then be compared across these 4 groups. A recent systematic review indicates that this combination approach was used in eight pediatric studies (1 longitudinal and 7 cross sectional) and all eight of these studies demonstrated that the individuals in the high MVPA / low SB combination had lower measures of obesity compared to individuals in the low MVPA / high SB combination (5,65–71).

The same limitations and assumptions discussed above under section 2.11.1 would apply to this analytical approach. Another challenge that would arise if this approach were used across the four physical activity domains is that a total of 12 different combination groups would be created. This would make it challenging to obtain a large enough sample size for each groups and it would become unwieldy to make comparisons across the 12 groups. Furthermore, as no guidelines exist for each specific domain, defining what high and low values are would be problematic.
2.11.3 Isotemporal Substitutions

Another statistical approach that has been used to evaluate the associations between different physical activity intensities and health outcomes is isotemporal substitution regression modelling (5,13,72). This approach involves using regression analysis to estimate whether substituting a given amount of time spent in one physical activity intensity with an equivalent amount of time in another intensity is associated with changes in health measures. The predictor variables in these regression models include the time spent in each specific physical activity intensity and the total time spent in all physical activity intensities. Single intensities are then dropped from the model in order to understand how replacing them affects the health outcomes.

Consider the following example of an isotemporal substitution modelling study. Aggio et al. estimated whether displacing time in LIPA and SB with equal time spent in MVPA was associated with body fat in 450 5-15 year olds (5). Results demonstrated that replacing 10 minutes of SB with an equivalent time in MVPA was associated with a decrease in body fat % (\(\beta = -4.187, p<0.05\)) and that replacing 10 minutes of LIPA with an equivalent time spent in MVPA was associated with a similar decrease in body fat % (\(\beta = -4.961, p<0.05\)) (5,73).

The key limitation of this regression approach reflects the Euclidean geometry issue previously explained under 2.9.1 (i.e., it assumes time is unconstrained). It is also important to note that the isotemporal substitution provides estimated effects of activity substitution as it based on observational data and not experimental data.

2.11.4 Compositional Analysis

Finally, a compositional analysis framework has been used to understand how all physical activity intensities collectively are associated with health outcomes. Compositional analysis is based on the notion that each movement intensity represents co-dependent relative
amounts of time within a constrained time frame (i.e., % of 24-hours spent at a specific intensity). Because of the compositional and constrained nature of the data, statistical approaches that are appropriate for compositional data are used (74,75). These approaches involve using a log-ratio to transform the data and then applying standard regression methods to the transformed data (76).

Carson et al. used the compositional data analysis framework to investigate the relationships between physical activity intensities (i.e. physical activity, sedentary time, and sleep duration) and a variety of health indicators (i.e. BMI-z, waist circumference, systolic blood pressure, diastolic blood pressure) among a large and representative sample of 6-17 year olds (77). The results indicated that, relative to the other movement behaviours, time spent in SB was positively associated with BMI-z score (γSB = 0.58; p=0.011), and log waist circumference (γSB = 0.509; p<0.001) and negatively associated with aerobic fitness (γSB = -32.80; p<0.001) (77).

Time spent in LIPA, relative to other physical activity intensities, was significantly and positively associated with BMI-z (γlight activity = 0.66; p<0.001), log waist circumference (γlight activity = 0.05; p=0.039), and log systolic blood pressure (γlight activity = 0.03; p=0.004) (77). Lastly, relative to the other physical activity intensities, time spent in MVPA was negatively associated with BMI-z (γMVPA = -0.32; p < 0.001), log waist circumference (γMVPA = -0.03; p = 0.012), log systolic blood pressure (γMVPA = -0.02; p < 0.001), log diastolic blood pressure (γMVPA = -0.02; p = 0.007), and was positively associated with aerobic fitness (γMVPA = 21.95; p < 0.001) (77). These results support the importance of MVPA for optimal health in children and adolescents. The results from change matrices demonstrating the effect of reallocating 10 minutes of time from one movement behaviour to another indicate that the biggest effect observed across cardio-metabolic health indicators was seen when taking 10
minutes of MVPA and putting it into the other movement behaviours (77). This was predominantly seen with SB where taking 10 minutes away from MVPA and putting it into sedentary time, LIPA, and sleep resulted in a 5.1%, 1.2%, and 1.1% increase in BMI z-score, respectively (77). Interestingly, these results were asymmetrical (i.e. taking 10 minutes away from sedentary time, LIPA, and sleep and putting it into MVPA resulted in a less than 1% decrease in BMI) (77). The authors suggested that this asymmetry may be explained by the exercise physiology principles of overload and reversibility where significant decreases in metabolic and exercise capacity occur rapidly with inactivity, while overloading the system with increased activity results in slower progressive increases in exercise capacity (77). Additionally, taking 10 minutes away from SB, which accounts for a large portion of the 24-hour period, is a much smaller change than taking 10 minutes of MVPA, which accounts for a small portion of the day (77).

Using a compositional data analysis approach to study the physical activity domains would involve calculating what proportion of physical activity time was spent in each physical activity domain, using a log-ratio to transform the data, and then applying standard regression techniques to the data. Unfortunately, this approach would not be feasible if there are 0 values for any participants for any of the physical activity domains as the log-ratio transformation could not be performed on 0 values. This will undoubtedly be the case as not all children perform in all domains of physical activity (e.g., the participation rate in organized sport is not 100%).

2.12 Summary

The amount of time a 10-13 year old spends in a particular domain of physical activity may have a large influence on a child’s cardio-metabolic health, however the results of the current literature examining these relationships are not consistent. One pathway by which
physical activity influences health is by increasing energy expenditure, and studies have shown that activities which contain more minutes of MVPA result in more favourable cardio-vascular fitness and obesity measures. As the intensity of movement differs between the four domains of physical activity and as the time spent in one domain may displace the time otherwise spent in another, understanding the relative contributions of each domain to cardio-metabolic health is of public health priority. The literature has also shown that simply being outdoors while participating in physical activity can influence health through pathways unrelated to the FITT principles, such as a parasympathetic response to natural, green environments. As this is a salient feature of both active transportation and outdoor active play, but not of curriculum-based physical activity or organized sport, the health benefits of the time spent in one domain may differ from an equivalent amount of time spent in another.

Though there is a fair amount of research which examines the individual physical activity domains and their influence of health, very few examine more than one domain, and no studies, to my knowledge, examine the four domains presented in this thesis. This study aimed to understand the independent associations between the four domains of physical activity and selected cardio-metabolic risk factors in children, and to gain an understanding of the health effects of substituting in one domain of physical activity with another.

2.13 References:


17. ParticipACTION. The Biggest Risk is Keeping Kids Indoors. The 2015 ParticipACTION


Chapter 3

Does Replacing Time Spent Participating in one Domain of Physical Activity with Time Spent in Another Influence Cardio-Metabolic Health in Children?
3.1 Abstract:

Purpose: The purposes of this study of 10-13 year old children were to: (1) determine if time spent in different domains of physical activity were independently associated with selected cardio-metabolic risk factors, and (2) estimate whether replacing time in one domain of physical activity with time in another domain of physical activity was associated with changes in cardio-metabolic risk factors.

Methods: 385 children aged 10-13 years were studied. Participants wore a Garmin Forerunner 220 GPS watch, an Actical accelerometer, and completed an activity log for 7 consecutive days during the school year. Data from these measures was used to estimate average minutes/day spent in active transportation, outdoor active play, organized sport, and curriculum-based physical activity at school. Percent body fat, resting heart rate, and systolic blood pressure were measured using automated equipment. Isotemporal substitution regression models were used to estimate changes in cardio-metabolic risk factors that occurred when time spent in each domain of physical activity was replaced with an equivalent amount of time in another domain.

Results: After adjusting for covariates, outdoor active play was associated with body fat % (β = - .058, 95% CI = -.095, -.021) and organized sport was associated with resting heart rate (β = - .040, 95% CI = -.071, -.009). In the isotemporal substitution models, replacing 10 minutes/day of organized sport with outdoor active play was favourably associated with body fat (β = -.048, 95% CI = -.094 to -.002) and replacing 10 minutes/day of active transportation with organized sport was favourably associated with resting heart rate (β = -.109, 95% CI = -.197, -.020).

Conclusion: These findings suggest that replacing time spent in organized sport with an equal amount of time in active play may have beneficial effects on body fat and that replacing time spent in active transportation with an equal time in organized sport may improve resting heart
rate. No significant effects were observed when curriculum-based physical activity was replaced by another domain of activity.
3.2 Introduction

The importance of physical activity is well documented and indicates that more active children have a better physical, mental, and social health (1–4). Unfortunately, the physical activity levels of children have been declining in recent years (5). In Canada, only 9% of 5-17 year olds meet public health guidelines for physical activity on a daily basis (1,6).

Despite the fact that a lack of time is a common barrier to physical activity participation (7,8), oftentimes the message conveyed to young people, caregivers, educators, and health professionals is that children should increase the amount of time they engage in physical activity (9). An alternative to increasing the time spent in physical activity is to improve the quality of the physical activity experiences per unit of time by focusing on the domain of physical activity that children are doing when they are active. In children, the main domains of physical activity are organized sports and programs (e.g., soccer game, basketball practice, competitive dance), active transportation (e.g., walking to school), curriculum-based activities at school (e.g., physical education), and outdoor active play (e.g., climbing trees, road hockey) (10).

To our knowledge, previous studies have not examined whether the cardio-metabolic health benefits differ according to the domain of physical activity. However, such differences may exist because the intensity of movement, which has an impact on health (11–15), differs across the different domains of physical activity (1,6,9,16–19). Furthermore, exposure to nature and the outdoors, which occurs for all active travel and outdoor play but only some organized sports and curriculum-based activities, could impact health via a parasympathetic response to natural green environments (20,21) and exposure to Vitamin D (22).

The purposes of this study were to: 1) examine whether each domain of physical activity is independently associated with selected cardio-metabolic risk factors among children, and 2)
estimate whether replacing time spent in one domain of physical activity with an equivalent amount of time spent in another domain of physical activity was associated with cardio-metabolic risk factors. The cardio-metabolic risk factors examined were body fat %, systolic blood pressure, and resting heart rate. This is an important topic to address because only a finite amount of time within a child’s day can be spent engaging in physical activity and changing the domain of physical activity may provide an avenue for benefiting a child’s health if the time they devote to physical activity cannot be increased.

3.3 Methods

3.3.1 Study design and population

Data are from the Active Play Study, a cross-sectional study conducted in the Physical Activity Epidemiology Laboratory at Queen’s University. Data were collected between January 2015 and December 2016. A total of 458 children aged 10 to 13 years from Kingston, Ontario participated. In order to be included in the analyses for the present study, the participants had to have the opportunity to participate in each of the four domains of physical activity. Therefore, 73 children who participated in the study during a school break, such as the summer holiday in July and August, were excluded because they did not have the opportunity to participate in curriculum-based physical activity. The final sample considered in the present study therefore included 385 participants.

Participants were recruited through word of mouth, social media, and advertisements distributed in local schools, community centres, and retail outlets (see example in appendix A, page 68). Participation was balanced across the four seasons and an equal number of boys and girls and of 10, 11, 12, and 13 year olds participated. Furthermore, participants were sampled from Kingston’s 12 electoral districts in proportion to the population of 10-13 year olds in these
districts (23). All participants and a parent or guardian provided written informed consent prior to participation (Appendix B, page 70). Participants were given $40 once they had returned both physical activity measurement devices and the activity logs. The study was approved by the General Research Ethics Board at Queen’s University (Appendix C, page 85).

3.3.2 Physical Activity Exposure Measures

Average time per day spent in each of the different domains of physical activity was assessed over 7 consecutive days using a combination of data from an Actical accelerometer (Philips Respironics, Murrysville, Pennsylvania, USA), Garmin Forerunner 220 GPS watch (Garmin Ltd., Schaffhausen, Switzerland), and an activity log.

The Actical is an omnidirectional accelerometer that measures movement in all directions. Participants were instructed to wear the accelerometer on an elasticized belt over their right hip at all times, except when participating in water based activities. The accelerometers were programmed to measure physical activity continuously in 15-second epochs, resulting in a total of 40,320 individual 15-second epochs over the 7 day measurement period.

In addition to the accelerometer, participants wore a Garmin Forerunner 220 GPS watch, which recorded their geographic location every 2 seconds to 2 minutes, depending on satellite signal availability. Participants were instructed to put on the watch soon after waking, to turn on the GPS logger function, and to continue wearing the watch until bedtime. After data collection, the GPS data were checked to locate missing GPS data that occurred when the satellite signal was lost, which in most instances happened when a participant entered a large building. When this occurred, the coordinates of the centre of the building were entered for the entire time they were in the building.
During the 7 day physical activity measurement period participants also completed an activity log where they recorded times and reasons they removed the accelerometer and GPS watch, their sleep times, the times they participated in organized sports and programs, and the times they performed outdoor chores (Appendix E, page 92). The times recorded in the activity logs were all manually checked by visually inspecting the accelerometer data in a graph using Actical software. Adjustments were made to the recorded times when recording errors were observed.

The data from the Actical accelerometer and Garmin GPS watch were merged using Personal Activity and Location Measurement System (PALMS) software (University of California San Diego, San Diego, California, USA). This involved assigning each 15-second epoch, recorded by the accelerometer, to latitude and longitude coordinates recorded by the GPS watch during that interval. Each 15-second epoch was then flagged to indicate whether or not it occurred during a trip. PALMS identified trips using a validated algorithm that is based on sequential GPS points that covered ≥100 m with a speed of ≥1 km/h lasting at least three minutes in duration (24). The software allowed for pauses in travel of up to three minutes to account for traffic lights and other brief stops. Once identified in PALMS, the travel modality of each trip was classified as walking, bicycling, or vehicle based on travel speed. Trips with a 90th percentile of speed ≥25 km/h were classified as vehicle trips, trips with a 90th percentile of speed ≥10 km/h and <25 km/h were classified as bicycle trips, and trips with a 90th percentile of speed ≥1 km/h and <10 km/h were classified as walking trips (24). Each of these trips identified by PALMS were individually checked by visually inspecting all of the GPS coordinates for that trip in Google Maps (Google, Mountain View, California, USA). During these visual inspections we identified and then deleted a number of false positive trips. An example of a false positive trip is
a trip identified by PALMS that, upon visual inspection, was found to occur on school grounds
during the recess period. This example reflected outdoor active play and not active
transportation.

The next data processing step involved importing the merged accelerometer-GPS files
into ArcMap version 10.4 software (Esri, Redlands, California, USA), where the latitude and
longitude coordinates were geocoded into a map layer. A second layer that included the
footprints of all buildings within Kingston was opened and the layers were joined to identify
which of the latitude and longitude points were within a building (indoors) and which were not
within a building (outdoors).

The resultant files were then opened in SAS version 9.4 software (SAS Inc., Carry, North
Carolina, USA) where they were merged with data from the activity logs as well as school
calendars (i.e., school days vs. non-school days, school start and end times, recess times). A
program was then developed to determine the time per day spent in active transportation,
organized sport, curriculum-based activity at school, and outdoor active play from these merged
data. The SAS program started by identifying and deleting all 15-second epochs for the invalid
days in which there was insufficient (< 10 hours) accelerometer and/or GPS watch wear time
(25). Then, all epochs from participants with 4 or more invalid days were deleted from the
dataset (25).

Organized sport was identified in the merged dataset by flagging all 15-second epochs
that occurred during the organized sport times that were recorded on the log. Time spent in these
epochs were summed to determine the minutes per day spent in organized sport. Similarly, the
epochs that PALMS software flagged as occurring during active transportation were summed to
determine the minutes per day spent in active transportation.
The identification of curriculum-based physical activity, such as physical education class and daily physical activity (DPA), started by flagging all epochs that occurred during school curriculum time on school days, but not during a scheduled recess period. Using an algorithm that was designed to be used within our study sample, we then identified within the school curriculum time the time that was spent in physical activity. This algorithm has a sensitivity of 78% and a specificity of 92%. It was developed using a database of accelerometer data based on a subset of 92 participants that captured known physical education classes, DPA classes, and class time that was devoted to other curriculum areas (e.g., math, science, reading).

The identification of outdoor active play started by flagging all 15-second epochs that could not have occurred during outdoor active play because it occurred when one or more of the following conditions were met: 1) time in bed, 2) indoors, 3) school curriculum time (but not recess time) on a school day, 4) during a vehicle trip, 5) while engaging in active transportation, 6) while participating in an organized sport, or 7) while performing work or chores. All of the 15-second epochs that were not flagged in the proceeding step were then classified as either occurring during outdoor active play or as sedentary time spent outdoors using a specifically designed algorithm that has a specificity of 85%, sensitivity of 85%, and positive predictive value of 99%. The algorithm was developed using a database of accelerometer data captured during known outdoor active play and outdoor sedentary behaviours in a subset of 50 participants.

3.3.3 Cardio-metabolic Risk Factor Outcome Variables

Non-invasive cardio-metabolic risk factors were measured including measures of body fat %, resting heart rate, and systolic blood pressure. Standing height was measured to the nearest 0.1cm using a portable stadiometer (SECA model 213, SECA GmbH & Co., Hamburg,
Germany) and body weight was measured to the nearest 0.1 km using a Tanita BF-689 electronic scale (Tanita Inc. Tokyo, Japan). The scale was also used to estimate body fat % to the nearest 0.1% using bioelectrical impedance analysis. After a 5 minute seated rest in a quiet room, resting heart rate and blood pressure were measured using the automated BPTrue BPM-200 monitor (Bayside Medical Supplies, Hawkestone, Ontario, Canada). Six readings were obtained in 1-minute intervals. The average of the last 5 readings were used.

3.3.4 Confounding Variables

Several potential confounding variables associated with both physical activity and cardio-metabolic risk factors and available in The Active Play Study dataset were considered. These data were collected in questionnaires completed by child participants and their parents (Appendices F & G, pages 95 & 97) and consisted of age (26,27), biological sex (26), race (white or other, including mixed race) (28), family structure (dual or single parent household) (29), annual family income (≤$50,000, $50,001-$100,000, or ≥$100,001) (30), the frequency of fast food consumption (rarely, 2-3 times/month, ≥1 times/week) (31), and the frequency of snacking while engaging in screen based activities (continuous) (32).

3.3.5 Statistical Analysis

Statistical analyses were conducted using IBM SPSS version 22 (IBM, Armonk, New York, USA). Since 13.5% of variables contained some missing values, multiple imputation was performed. This simulation based technique was used to handle the missing data in a way which would result in valid statistical inference and would allow the data for all participants to be analyzed with complete data. Five iterations of multiple imputation were used based on existing precedence (33). The imputation model contained all exposures, outcomes, and covariates.
Estimates obtained from each of the five imputations were pooled to create the final estimates presented in the paper.

Conventional descriptive statistics were used to describe the sample. Because the cardio-metabolic risk factors were not normally distributed, they were transformed using Templeton’s two-step approach (34) and converted to z-scores prior to regression analyses. General linear models were used to examine the associations between time in the different domains of physical activity and the cardio-metabolic risk factors. Time was expressed in 10 min/day increments. Thus, the coefficients from the regression models represent the change in the cardio-metabolic risk factor z-scores for each additional 10 min/day of physical activity. Confounding variables were included in the regression models if they were associated with the cardio-metabolic risk factor being examined using a conservative p value of <0.2.

Initially, separate regression models were run for each domain of physical activity. These are hereafter referred to as the single models. This was followed by regression models that included all four domains of physical activity. These models are hereafter referred to as the partition models. The partition models estimated the association for each domain of physical activity while holding time in the other domains constant. Next, isotemporal substitution models were used to estimate the time-substitution effects of one domain of activity with another. For the isotemporal substitution models, total time spent in each of the four domains combined was included as a predictor variable in addition to time spent in each specific domain. Then, in a series of regression models, time spent in the individual domains was removed to estimate whether replacing time spent in that domain by another was associated with changes in the cardio-metabolic risk factors. For example, to estimate the influence of replacing 10 min/day of organized sport with 10 min/day of outdoor active play on body fat %, outdoor active play was
removed from a model that included organized sport time as the exposure while adjusting for total physical activity time and time spent in active transportation, curriculum-based physical activities, and relevant covariates.

### 3.4 Results

Socio-demographic characteristics of the 385 participants are in Table 3.1 (page 48). Approximately half were boys and the average (SD) age was 11.5 (1.1) years. The majority were of white race and lived in dual parent households. On average, participants spent 38.1 (28.0) min/day in outdoor active play, during which time 11.2 minutes were spent in MVPA, 17.7 minutes in LIPA, and 9.4 minutes we spent sedentary. 33.0 (35.6) min/day, on average, were spent in organized sport with 8.2 minutes spent in MVPA, 10.9 minutes in LIPA, and 14.5 minutes sedentary. Children spent an average of 22.3 (14.9) min/day in curriculum-based physical activities at school (e.g., physical education), with 7.3 minutes spent in MVPA, 7.6 minutes in LIPA, and 4.3 minutes sedentary. Lastly, children spent an average of 15.8 (13.0) min/day in active transportation, during which time 9.9 minutes were spent in MVPA, 5.0 were spent in LIPA, and 1.6 sedentary. The mean body fat %, resting heart rate, and systolic blood pressure values were 20.7 (8.0) percent, 79 (11) beats/min, and 97 (9) mmHg, respectively.
Table 3.1 Socio-demographic characteristics of participants (N = 385)

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>195</td>
<td>50.6</td>
</tr>
<tr>
<td>Female</td>
<td>190</td>
<td>49.4</td>
</tr>
<tr>
<td><strong>Age (years)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>94</td>
<td>24.4</td>
</tr>
<tr>
<td>11</td>
<td>95</td>
<td>24.7</td>
</tr>
<tr>
<td>12</td>
<td>96</td>
<td>24.9</td>
</tr>
<tr>
<td>13</td>
<td>100</td>
<td>26.0</td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>342</td>
<td>88.8</td>
</tr>
<tr>
<td>Other</td>
<td>43</td>
<td>11.2</td>
</tr>
<tr>
<td><strong>Family Structure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dual Parent</td>
<td>337</td>
<td>87.5</td>
</tr>
<tr>
<td>Single Parent</td>
<td>48</td>
<td>12.5</td>
</tr>
<tr>
<td><strong>Family Income ($ CDN/Year)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\leq$ 50,000</td>
<td>64</td>
<td>16.6</td>
</tr>
<tr>
<td>$50,001$-$100,000$</td>
<td>112</td>
<td>29.1</td>
</tr>
<tr>
<td>$&gt; 100,000$</td>
<td>209</td>
<td>54.2</td>
</tr>
</tbody>
</table>

Total physical activity, which reflected the sum of time spent in the four different domains of physical activity, was significantly associated with body fat but not resting heart rate or systolic blood pressure (Table 3.2, page 49). The results indicated that each 10 min/day increase in total physical activity was associated with a 0.31 (95% CI = 0.11, 0.51) decrease in body fat % z-score. The results of the single models for outdoor active play, which adjusted for relevant covariates but not the other domains of physical activity, indicated that each 10 min/day increase in outdoor active play was associated with a .058 (95% CI = .21, .95) decrease in body fat % z-score (p=.002). Outdoor active play was not associated with heart rate or blood pressure. The results of the single models for organized sport indicated that each 10 min/day increase was associated with a 0.04 (95% CI = .01, .07) decrease in resting heart rate z-score (p=.011). Organized sport was not associated with the other two cardio-metabolic risk factors. In addition, active transportation and curriculum-based activities were not associated with any of the cardio-metabolic risk factors. The pattern and statistical significance of results for the partition models,
wherein the results for each domain of physical activity were adjusted for each other, were identical to the patterns for the single models (Table 3.2).

**Table 3.2.** Relationships between time spent in total physical activity and the different domains of physical activity with body fat, resting heart rate, and blood pressure.

<table>
<thead>
<tr>
<th>Cardio-metabolic Risk Factor</th>
<th>Total Physical Activity</th>
<th>Outdoor Active Play</th>
<th>Organized Sport</th>
<th>Active Transportation</th>
<th>Curriculum-Based Physical Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Body Fat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Model(^a)</td>
<td>-.031 (-.051, -.011)(^c)</td>
<td>-.058 (-.095, -.021)(^c)</td>
<td>-.006 (-.034, .023)</td>
<td>-.035 (-.116, .047)</td>
<td>-.048 (-.113, .017)</td>
</tr>
<tr>
<td>Partition Model(^b)</td>
<td>N/A</td>
<td>-.058 (-.095, -.021)(^c)</td>
<td>-.010 (-.038, .019)</td>
<td>-.014 (-.095, .069)</td>
<td>-.045 (-.109, .020)</td>
</tr>
<tr>
<td>Resting Heart Rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Model(^a)</td>
<td>-.013 (-.035, .009)</td>
<td>.008 (-.037, .053)</td>
<td>-.040 (-.071, -.009)(^c)</td>
<td>.082 (-.001, .166)</td>
<td>-.019 (-.091, .054)</td>
</tr>
<tr>
<td>Partition Model(^b)</td>
<td>N/A</td>
<td>-.002 (-.048, .044)</td>
<td>-.037 (-.068, -.005)(^c)</td>
<td>.072 (-.015, .159)</td>
<td>-.015 (-.087, .057)</td>
</tr>
<tr>
<td>Systolic Blood Pressure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Model(^a)</td>
<td>-.014 (-.036, .007)</td>
<td>-.013 (-.057, .031)</td>
<td>-.014 (-.045, .018)</td>
<td>-.015 (-.096, .066)</td>
<td>-.021 (-.092, .050)</td>
</tr>
<tr>
<td>Partition Model(^b)</td>
<td>N/A</td>
<td>-.013 (-.058, .032)</td>
<td>-.015 (-.047, .017)</td>
<td>-.014 (-.098, .070)</td>
<td>-.018 (-.089, .053)</td>
</tr>
</tbody>
</table>

*Note:* Data presented as β (95% confidence interval) and represent the change in the cardio-metabolic risk factor z-scores for each 10 min/day change in the physical activity variables.

\(^a\) Adjusted for confounding variables only.

\(^b\) Adjusted for the other domains of physical activity and the confounding variables.

\(^c\) Statistically significant (p<0.05)
Table 3.3 (page 50) presents the results of the isotemporal substitution models. The domain of physical activity being displaced are in the rows while the domain of physical activity being substituted are in the columns. Of all the substitutions, only the organized sports vs. outdoor active play substitution and the active transportation vs. organized sport substitution were statistically significant. Replacing 10 min/day of organized sport with 10 min/day of outdoor active play was associated with favourable changes in body fat %. Replacing 10 min/day of active transportation with 10 min/day of organized sport was associated with favourable changes in resting heart rate.

Table 3.3. Estimated changes in cardio-metabolic risk factors attributable to substituting 10 min/day of one domain of physical activity with 10 min/day of another domain of physical activity.

| Cardio-metabolic Risk Factor and Domain of Physical Activity Being Replaced | Domain of Physical Activity being Substituted |
|---|---|---|---|---|
| | Outdoor Active Play | Organized Sports and Programs | Active Transportation | Curriculum-Based Physical Activity |
| **Body Fat %** | | | | |
| Replace Outdoor Active Play | Dropped | .048 (.002, .094)a | .044 (-.051, .140) | .013 (.061, .087) |
| Replace Organized Sports and Programs | -.048 (-.094, -.002)a | Dropped | -.004 (-.088, .081) | -.035 (-.108, .038) |
| Replace Active Transportation | -.044 (-.140, .051) | .004 (.081, .088) | Dropped | -.031 (-.135, .072) |
| Replace Curriculum-Based Physical Activity | -.013 (-.087, .061) | .035 (-.038, .108) | -.031 (-.072, .135) | Dropped |
| **Resting Heart Rate** | | | | |
| Replace Outdoor Active Play | Dropped | -.035 (-.091, .021) | .074 (-.036, .184) | .013 (-.104, .078) |
| Replace Organized Sports and Programs | .035 (.021, .091) | Dropped | .109 (.020, .197)a | .022 (-.057, .101) |
| Replace Active Transportation | -.074 (-.184, .036) | -.109 (-.197, -.020)a | Dropped | -.087 (-.199, .026) |
| Replace Curriculum-Based Physical Activity | .013 (-.078, .104) | -.022 (-.101, .057) | .087 (-.026, .199) | Dropped |
| **Systolic Blood Pressure** | | | | |
| Replace Outdoor Active Play | Dropped | -.002 (-.058, .055) | -.001 (-.106, .104) | -.005 (-.094, .084) |
| Replace Organized Sports and Programs | .002 (-.055, .058) | Dropped | .001 (-.085, .087) | -.003 (-.083, .076) |
| Replace Active Transportation | .001 (-.104, .106) | -.001 (-.087, .085) | Dropped | -.004 (-.113, .105) |
| Replace Curriculum-Based Physical Activity | .005 (.084, .094) | .003 (.076, .083) | .004 (.105, .113) | Dropped |

Note: Data presented as β (95% confidence interval) and represent the change in the cardio-metabolic risk factor z-scores for each 10 min/day substitution of one domain of physical activity with another domain of physical activity. All analyses were adjusted for the confounding variables.

a statistically significant (p<0.05)
3.5 Discussion

This study examined the relationships between different domains of physical activity and cardio-metabolic risk factors in a sample of 10-13 year olds. Outdoor active play was independently associated with body fat % and organized sport was independently associated with resting heart rate. Estimates from the isotemporal substitution models suggest that replacing time in organized sport with outdoor active play was favourably associated with body fat %, and that replacing time in active transportation with organized sport was favourably associated with resting heart rate.

We are unaware of prior studies of children that have investigated whether replacing time spent in one domain of physical activity within time spent in another domain of physical activity influences health outcomes. Thus, the results of the isotemporal substitution models provide novel findings. Previous studies have examined the association between specific domains of physical activity and health outcomes, and the next three paragraphs discuss how the findings of these studies compare to our findings.

In our study, body fat % was associated with outdoor active play but not the other domains of physical activity. Other studies have also shown that organized sport (35,36), curriculum-based physical activity such as physical education (37,38), and active travel (18,39,40) are not as strongly associated with obesity measures. A possible explanation for why organized sport is not associated with body fat % or other obesity measures could be that activity levels are not of a long enough duration to elicit changes (35). The lack of association between curriculum-based physical activity and body fat % could be explained by the lack of qualified instructors (41) and policies that enforce quality, physical education (42–44). Thus, the majority of time in a physical education class is spent sedentary and only a small fraction is spent...
engaging in moderate-to-vigorous physical activity (44). Similarly, the time spent in active transportation may not be sufficient enough to elicit benefits (45). Indeed, 60% of participants in this study accumulated ≤15 min/day of active transportation and this volume of active transportation is unlikely to result in a high enough energy expenditure to significantly influence body fat % (45).

In our study organized sport was the only domain of physical activity that was associated with resting heart rate. Furthermore, replacing time in active transportation with organized sport was favourably associated with resting heart rate. Prior studies have also found an association between sport participation and resting heart rate (46–48). Furthermore, studies have demonstrated that physical activities that include more minutes at a moderate-to-vigorous intensity are more favourably associated with resting heart rate (46,47). The higher intensity of organized sport may therefore explain why it was the only domain of physical activity associated with heart rate in our analyses. Studies wherein children wore accelerometers during several different organized sports indicated that, on average, 32% of the time is spent at a moderate-to-vigorous intensity (49). The comparable figures are 27% for outdoor active play performed during recess and 12% for physical education (49). For active transportation, which has little variation in intensity, the average walking speed for children is in the moderate intensity range and little or no vigorous activity is performed (49).

None of the different domains of physical activity were associated with systolic blood pressure z-scores in our sample. While there is evidence of an association between physical activity and blood pressure in pediatric populations (50,51), this association has not been observed consistently in all studies (52). The lack of association in our study may reflect the low variability and the lack of ‘at risk’ blood pressure values. In fact, in our sample less than 2% of
participants had ‘at risk’ systolic blood pressure values, which are defined when values exceed the 90th percentile for the child’s gender, age, and height (53,54) (data not shown). By comparison, nearly 8% had overweight or obesity based on similar criteria for the obesity measures (data not shown).

Some of the findings from this manuscript have important public health implications. First, outdoor active play was significantly associated with a healthier body fat, and therefore might be an important area for intervention. As outdoor active play is largely cost-free and can be performed by almost all children in a variety of outdoor locations at any time of year and day of the week, increasing the time a child spends in this domain could be an affordable and efficient solution for children to accumulate more physical activity. Secondly, the associations between the time spent in organized sport and a decreased resting heart rate are also of public health relevance given the long lasting effects of heart rate on cardiovascular health (55).

The limitations of this study warrant discussion. First, since this was a cross-sectional study it does not establish causation. Second, the results may not be generalizable beyond the 10-13 year old age range of the study sample. Third, the study did not measure all possible domains of physical activity, such as active play performed indoors and lighter intensity activities of daily living. Fourth, this study only measured a child’s activity over the course of 7 days. It is possible that the activity captured during this time frame was not representative of the child’s habitual physical activity. Lastly, the isotemporal substitution models are based on observational data and they only provide estimates of what could happen in an intervention setting.

3.6 Conclusion

This study aimed to understand the independent associations between the four domains of physical activity and selected cardio-metabolic risk factors in children, and to gain an
understanding of the health effects of substituting in one domain of physical activity with another. Outdoor active play and organized sport were the only two domains of physical activity that were related to a cardio-metabolic risk factor. Future research is needed to understand the difference in intensity between these four physical activity domains as this may be a key factor in predicting their role on cardio-metabolic health.

3.7 References


10. Brockman R, Fox KR, Jago R. What is the meaning and nature of active play for today’s


35. Vella SA, Cliff DP, Okely AD, Scully ML, Morley BC. Associations between sports participation, adiposity and obesity-related health behaviors in Australian adolescents. The


Chapter 4

General Discussion

4.1 Summary of Key Findings

The objectives of this thesis research were to determine if time spent in each physical activity domain was independently associated with selected cardio-metabolic risk factors, and to estimate whether replacing time spent in each domain with an equivalent amount of time spent in the other domains was associated with changes in cardio-metabolic risk factors.

385 children aged 10-13 from Kingston, Ontario took part in this cross-sectional study. Their physical activity was measured over 7 days. Cardio-metabolic risk factors included measures of body fat %, resting heart rate, and systolic blood pressure. Multivariable regression models were used to examine the associations between time spent in each of the four physical activity domains and the cardio-metabolic risk factors. Isotemporal substitution regression models were used the estimate whether replacing time spent in one physical activity domain with an equal amount of time in another domain was associated with changes in the cardio-metabolic risk factors.

The key findings were that outdoor active play was independently associated with body fat % and organized sport was independently associated with resting heart rate. Estimates from the isotemporal substitution models suggested that replacing time spent in organized sport with equal time in outdoor active play was favourably associated with body fat % and that replacing time spent in active transportation with an equal amount of time in organized sport was favourably associated with resting heart rate.
4.2 Overall Strengths of the Thesis

There are many notable strengths to this thesis. Firstly, the meticulous and careful measurement of both the exposure and outcome variables limited the potential for bias and misclassification. Physical activity was largely measured objectively using data collected from an Actical accelerometer and Garmin GPS watch. Many similar studies have used self- or parental-reported measures such as outdoor time (as a proxy for outdoor play) (1–3) or active transportation to school (which only captures one travel destination) (4–6), which could have led to misclassification of physical activity variables and biased results. Additionally, the cardio-metabolic risk factors were measured objectively using validated techniques. For example, resting heart rate and systolic blood pressure were measured using an automated blood pressure cuff (BpTRU), which is more accurate by comparison to manual sphygmomanometry (7), the technique used in most research studies.

The generalizability to other groups outside of the study sample and conditions is also a strength of this study. The sample used in this research consisted of 385 children balanced across sex, age, season, and Kingston’s electoral districts to ensure proportional representation across these factors as well as diversity in demographic characteristics. Assuming our study was internally valid, this would allow our results to be generalizable to other 10-13 year olds.

Finally, the use of multiple imputation was a strength of this study. This allowed all participants to be included in the final analyses, therefore preserving the sample size and statistical power (8). The multiple imputation technique used in these analyses is advantageous because it results in unbiased estimates and is a more valid approach for handling missing data than other approaches that are commonly used for missing data such as limiting the analyses to cases with complete data or imputing the sample average for all missing values (8).
4.3 Overall Limitations of the Thesis Research

There are several important limitations to the thesis research. Firstly, definitive causal evidence was not provided. In the field of epidemiology, causality is often determined using Sir Bradford Hill’s criteria of causation, which commonly includes 5 principles. At least two of these criteria for causation - temporality and strong associations - were not met in this study. Temporality refers to the necessity that the cause preceded the effect in time (9). As this study was of cross-sectional design, temporality could not be ascertained. The Hill criteria of causation argues that the stronger the association, the more likely it is that there is causality (9). In our study, the strength of the statistically significant associations were weak to moderate and not strong. With that being said, this thesis research did meet some of Hill’s criteria. Plausibility, which refers to the scientific plausibility of an association between an exposure and an outcome, was a criteria met in this study. The mechanisms that could explain these associations were discussed in earlier chapters. Additionally, there is some evidence of consistency, which refers to the repeated observation of an association in different populations under different circumstances. For example, in addition to this study, several previous studies have found no significant association between active transportation and cardio-metabolic health in children (5,10,11).

Another key limitation is that the isotemporal substitution models only provided an estimated effect of physical activity substitution as they were based on observational data and not experimental data. The results therefore may not hold true if the activity time substitution occurred in an intervention setting.

A potential third limitation of this study is a selection bias. This form of bias occurs when there is a systematic difference between those who participated in the study and those who chose not to participate. Participation in this study was voluntary. This could have potentially
introduced a selection bias as the children who participated in the study may have been different than those who did not. This is a possibility as each participant knew prior to volunteering that this was a physical activity study, and this knowledge could have resulted in a more physically active sample than the target population. With that being said, our research team found that a primary determinant for participating in the study was the monetary compensation ($40) rather than the desire to learn more about their physical activity. Additionally, since the goal of this study was to understand the etiological relationships between the 4 activity domains and cardio-metabolic health, a selection bias could have only occurred if the relationship between the time spent in the four domains of activity and cardio-metabolic health differed systematically based on study selection, which is highly unlikely.

Lastly, the study did not measure all possible domains of physical activity, such as active play performed indoors. Active play performed indoors was not measured as time spent in this activity domain versus time spent performing common daily tasks (i.e. stair climbing, walking around the house) were indistinguishable with the data we had available. Additionally, the decision to focus on outdoor active play was based on a body of evidence which suggests that the benefits of outdoor play far outweigh indoor play, which is more likely to be sedentary and screen based, possibly increasing cardio-metabolic risk (12).

4.4 Future Research Directions

Limited research has investigated the associations between the physical activity domains and health in children. Furthermore, to my knowledge no research has examined whether substituting time in one domain with time in another is beneficial for a child’s health. Therefore, it is important to replicate these findings in other samples. Future research is also needed to understand the difference in intensity between and within these four physical activity domains as
this may be a key factor in predicting their role on cardio-metabolic health. Bridging this knowledge gap would allow for informed public health interventions aimed at increasing a child’s daily physical activity in an efficient manner. Furthermore, longitudinal research and intervention studies are needed to gain a deeper appreciation for the isotemporal relationships. For example, an intervention study could investigate the effects of replacing the time a child would normally spend playing at recess with an organized sport activity for an entire year or semester. This would allow researchers to understand the potential effects of substituting time spent in outdoor active play with time in organized sport on a child’s cardio-metabolic risk in a real life setting. Lastly, this research focused on physical health outcomes. It would be beneficial to gain an understanding of the mental and social implications of these substitutions as replacing time in one domain with time in another might have a significant effect on a child’s mental well-being.

4.5 Public Health Relevance

Increasing children’s physical activity levels is an important public health priority. Recent evidence suggests that increasing time spent in outdoor active play may be beneficial for a child’s overall physical activity levels and cardio-metabolic health (13–15).

The findings from the manuscript in this thesis suggest that outdoor active play is significantly associated with healthier body fat %. As outdoor active play is largely cost-free and can be performed by the majority of children in a variety of outdoor locations at any time of the year, increasing the time a child spends in this domain could be an affordable and efficient solution for children to accumulate more minutes of physical activity each day. There are many times throughout the day when children could engage in outdoor play such as afterschool, during recess, and after dinner. Furthermore, children can engage in outdoor play on weekdays and
weekends across the entire calendar year. Thus, there may be more opportunities for children to engage in outdoor active play than the other physical activity domains.

The association between the time spent in organized sport and resting heart rate is also of public health relevance. A lower resting heart rate in children is associated with decreased levels of obesity and pre-hypertension, which could have long lasting effects on their cardiovascular health (16). Furthermore, organized sport may provide a child with benefits that extend beyond physical health. Sports provide the opportunity for the development of social skills otherwise not taught at home or in school (17), as well as foster an appreciation for sport and activity, which may continue throughout their lifetime. Since enrolling a child in organized sports can be expensive and could pose a financial burden for many parents, encouraging the development of subsidized sport programs at a municipal or provincial level may be an effective strategy to increase a child’s participation in organized sport.

Finally, as only a finite amount of time within a child’s day can be spent engaging in physical activity, and as the time spent in one domain of activity may displace the time spent in another, it is important to understand the relative contributions to cardio-metabolic health of each domain. The results from this study indicate that substituting time in one activity domain (i.e. organized sport) with an equal amount of time in another (i.e. outdoor active play), may benefit a child’s cardio-metabolic health without increasing total daily activity time. Emphasizing participation in domains with larger cardio-metabolic health benefit in lieu of those with little benefit may be a possible avenue for public health intervention.

4.6 Summary of MSc Research Experiences

My experience as a graduate student within the School of Kinesiology and Health Studies has allowed me to broaden my knowledge in the field of physical activity epidemiology.
Throughout the first year of my Master’s degree, I had the opportunity to take classes focused on the fundamentals of epidemiological methods and statistics, as well as complete an independent study which allowed me to learn more about physical activity epidemiology. Outside of the classroom, I had the opportunity to work as a research assistant for the Active Play Study which provided me with the opportunity to gain insight into primary data collection, data management, and data processing. In this position, which lasted just over half of my graduate studies, I was able to work with the participants and their families to organize study visits, and collect anthropometric, accelerometer, GPS, and survey data. Throughout my first year as a Master’s student, I aided in the processing, merging, and cleaning of GPS and accelerometer data which exposed me to several different software packages and different types of data.

During the second year of my degree, I conceptualized, executed, and critically evaluated my own thesis research using data collected from the Active Play Study. In the process, I continued assisting in the data cleaning process. Additionally, I gained a comprehensive understanding of SPSS statistical programming software through formatting, manipulating, and merging the data sets needed for my analysis. I also used SPSS to complete all of the statistical analyses, including the multiple imputation, and regression analyses. I was also responsible for interpreting my results and preparing my work in a written format for future publication of the manuscript and of this thesis. Finally, I had the opportunity to present my research at an international conference (International Society of Behavioural Nutrition and Physical Activity, June 2017).

4.7 Conclusion

In conclusion, the amount of time a 10-13 year old spends in a particular domain of physical activity may somewhat benefit their cardio-metabolic health. This being said, as only
two physical activity domains were significantly associated with cardio-metabolic health, future studies investigating the underlying mechanisms for why certain domains significantly influence health while others do not, could be warranted. It is hoped that the findings from this thesis will contribute to a growing body of literature on the importance of physical activity for a child’s cardio-metabolic health, while inspiring future research in this field.

4.8 References


Appendix A

Active Play Study Recruitment Advertisement
Physical Activity in Kingston Children

We are looking for 12-13 year olds to participate in a physical activity study at Queen’s University

Children who complete the study will earn $40!

This study will determine where and when children are physically active. It will also determine how different types of physical activity influence children’s health.

All 12-13 year olds who live and go to school in Kingston can participate.

Participation in this study involves the following:

1. Two 45 minutes visit to Queen’s University
2. Simple physical measures such as height, weight, and blood pressure.
3. Completing a survey on a computer
4. Wearing a small activity measurement device for 7 days

The total time commitment for participating is about 4 hours.

For more information please contact us:

Email:  Queens.Physical.Activity@gmail.com
Phone:  (613)533-6000 ext. 75401
Address:  501-28 Division St., School of Kinesiology and Health Studies, Queen’s University.
Website:  https://sites.google.com/site/paepilab/
Appendix B

Active Play Study Participant Letter of Information / Consent

Child and Parent / Guardian
Letter of Information / Consent for Child

Physical Activity Levels in Kingston Children

Principal Investigator: Dr. Ian Janssen
School of Kinesiology & Health Studies, Queen’s University
Kingston, Ontario
Phone: (613)533-6000 ext. 78631
E-mail: ian.janssen@queensu.ca

Co-Investigator: Dr. Michael McIsaac
Department of Public Health Sciences, Queen’s University
Kingston, Ontario
Phone: (613)533-6000 ext. 77460
E-mail: mcisaacm@queensu.ca

Research sponsor: Heart and Stroke Foundation of Canada

Purpose of the study

We want you to participate in this study. It is about children’s physical activity. Children’s physical activity levels are getting worse. We want to know why.

The purposes of this study are:

1. To determine how much active play, sport, and walking and biking children do.
2. To determine where children get physically active. Several locations will be looked at. These include homes, streets, playgrounds, fields, forests, schools, and arenas.
3. To determine how families, friends, and neighbourhoods affect physical activity.
4. To determine how physical activity affects health.
What will happen during the study?

You and your parent will come to Queen’s University for two visits. The visits will be 8 to 11 days apart. Each visit will last about 45 minutes. Your physical activity will be measured for 7 days between the two visits.

At the first visit we will explain the study to you. We will answer any questions you have. We will measure how tall you are and how much you weigh. We will measure your belt size. We will measure your heart rate and blood pressure using a small machine. These measures should not cause any pain or discomfort.

At the end of the first visit we will give you two small electronic devices. You will wear them for 7 days. They will measure your physical activity. The first device will measure how much physical activity you get. You will wear it around your waist on a belt. The second device looks like a watch. It will record your location on a map about every 30 seconds. It will tell us where you got your physical activity.

On the 7 days your physical activity is measured you should write when you remove the electronic devices. You should also write down times you go to bed and wake up. We will give you a diary to write this down.

On the second visit to Queen’s University you will return the two electronic devices. You will also answer some questions on a computer. This will take about 25 minutes. The questions will ask about things you do in your free time. The questions will also ask about your health.

Are there any risks to participating in the study?

Participating should not cause any harms. You do not have to answer questions that make you uncomfortable.

Are there any benefits to participating in the study?

The research will not benefit you directly. We hope to learn more about physical activity in children. We hope this will help us think of ways to get children to be more active.
Payment for participating

You will be given up to $40. You will receive $10 at the end of the first visit. You will be given $20 at the start of the 2\textsuperscript{nd} visit if you return the electronic devices in good condition. You will be given $10 at the end of the 2\textsuperscript{nd} visit. If you drop out of study, you can keep the money you have already received.

Confidentiality and privacy

We will make every effort to keep the information we obtain from you private. When we show the research findings we will not include private information about you. The information we obtain about you will be protected on our computers.

Legally required disclosure

Although we will protect your privacy, if the police request information we may be required to give it to them.

What if I change my mind about being in the study?

All parts of a research study are voluntary. You can drop out of the study at any time before it is done. There will be no penalties if you drop out. Also, any information you gave us will be destroyed if you choose.

Questions about the study

Questions can be asked to Dr. Ian Janssen. His contact information is shown at the top of this letter. Ethical concerns can be asked to the Chair of the General Research Ethics Board at chair.GREB@queensu.ca or 613-533-6081.

*This study has been granted clearance according to the recommended principles of Canadian ethics guidelines, and Queen’s policies.*
Physical Activity Levels in Kingston Children

CONSENT FORM FOR CHILD – Participant’s Copy

I have read and understood the attached information sheet or had it explained to me. I know that there may be no direct benefit to me for participating. I know that it is my choice to participate. I have been told about the study. I have had all of my questions answered. I know that any information collected about me will be kept private. No one will know that I participated in the study except for the research team. I know I am free to drop out of the study at any time. If I drop out it will not affect me or my family. I also know that I do not have to answer questions that make me feel uncomfortable. I have received a copy of the information sheet and consent form. I agree to participate in the study.

Your full name (Printed) ________________________________

Your signature: _______________________________________

Date: _________________________________________________

Would you be willing to be contacted about a potential follow-up study, understanding that you can always decline the request?

✓Yes

✓No
Participant ID: □□□□ □

Physical Activity Levels in Kingston Children

CONSENT FORM FOR CHILD – Research Team’s Copy

I have read and understood the attached information sheet or had it explained to me. I know that there may be no direct benefit to me for participating. I know that it is my choice to participate. I have been told about the study. I have had all of my questions answered. I know that any information collected about me will be kept private. No one will know that I participated in the study except for the research team. I know I am free to drop out of the study at any time. If I drop out it will not affect me or my family. I also know that I do not have to answer questions that make me feel uncomfortable. I have received a copy of the information sheet and consent form. I agree to participate in the study.

Your full name (Printed) ___________________________________

Your signature: __________________________________________

Date: __________________________________________________

Would you be willing to be contacted about a potential follow-up study, understanding that you can always decline the request?

Yes
No
Physical Activity Levels in Kingston Children

Principal Investigator: Dr. Ian Janssen
School of Kinesiology & Health Studies, Queen’s University
Kingston, Ontario
Phone: (613)533-6000 ext. 78631
E-mail: ian.janssen@queensu.ca

Co-Investigator: Dr. Michael McIsaac
Department of Public Health Sciences, Queen’s University
Kingston, Ontario
Phone: (613)533-6000 ext. 77460
E-mail: mcisaacm@queensu.ca

Research sponsor: Heart and Stroke Foundation of Canada

Purpose of the study

You and your child are invited to take part in this study on children’s physical activity. Children’s physical activity levels have declined in recent years and we hope to better understand children’s physical activity so that we can better work to increase their physical activity levels.

The purposes of this study are:

1. To determine the amount of different types of physical activities children do such as outdoor active play, organized sport, and active transportation (walking and biking).
2. To determine where children are when they engage in outdoor active play, organized sport, and active transportation. Several locations will be considered including the
child’s home, the homes of relatives and friends, streets, playgrounds, wooded areas, school grounds, sports facilities, etc.

3. To determine what factors of the family, home, and neighbourhood environment predict how much outdoor active play, organized sport, and active transportation children get.

4. To determine whether active play, organized sport, or active transportation predicts children’s physical and mental health.

**What will happen during the study?**

You and your child will be asked to come to the Physical Activity Epidemiology lab at Queen’s University (Room 501, 28 Division St) for two visits about 8-11 days apart. Each visit will last approximately 45 minutes. Your child’s physical activity will be measured over a 7 day period between the two visits.

During the first visit to the lab, details of the study will be explained to you and your child. The research team will answer any questions that you or your child have. We will then measure your child’s standing height, sitting height, weight, and waist circumference. We will also measure your child’s heart rate and blood pressure using an automated machine. These physical measurements are non-invasive and should not cause any pain or discomfort to your child.

At the end of the first visit, your child will receive two small electronic devices that they will wear for the next 7 days to measure their physical activity. The first electronic device is a physical activity monitor. It will measure how much physical activity your child gets. The physical activity monitor is worn around the hip on an elastic belt. It is very small (i.e., smaller than a book of matches). However, it is not waterproof. Your child will be asked to wear the physical activity monitor for 24/hours day for 7 days except the times when they will be in water.

The second electronic device is a GPS logger. The GPS logger looks like a sports watch and is worn around the wrist. This device will record your child’s geographic location about every 30 seconds. After the data has been collected the research team will determine where your child was when they were being active. Your child will be asked to wear the GPS logger for 7 days. They will take the GPS logger off at night so that its battery can be charged. Please note that the research team cannot track where child is while they are wearing this GPS logger.
During the 7 days your child’s physical activity is being measured, they will be asked to write down the times they remove their physical activity monitor. They will also be asked to write down times they go to bed and wake up. We will give them a diary to write down this information. Also, the research team will contact you by phone, e-mail, or text message (whichever is your preference) every morning. This will let us remind your child to wear the physical activity monitor and GPS logger. This will also allow you or your child to ask us any questions that may arise.

Following the 7 days of physical activity data collection, you and your child will be asked to return to the physical activity epidemiology lab for the 2nd and final visit. At this time, your child will be asked to return the physical activity monitor and GPS logger. Your child will also be asked to complete a ~25 minute questionnaire on the computer. This questionnaire will ask them about different types of physical activity that they do, their feelings about these physical activities, other ways that they spend their time (e.g., watching TV, doing homework), their mental health, and some of their eating behaviours. You will also be asked to complete a ~25 minute questionnaire on the computer. This questionnaire will ask for information about your family, your child’s physical activity, as well as some home and neighbourhood factors that may influence the ability of your child to be physical active.

**Are there any risks to participating in the study?**

It is unlikely that participating in this study will be associated with any harms or discomforts beyond those experienced in everyday life. The physical measures that we will obtain (e.g., height, blood pressure) are routinely used in children and are not associated with any known risk or adverse effect. The devices that your child will wear to measure their physical activity are similar to a belt and watch. These devices present no additional risk beyond those encountered in daily life while wearing these accessories. Finally, some of the items on the questionnaires might be deemed personal or sensitive by some people. You and your child do not need to answer questions that you do not want to answer or that make you feel uncomfortable.

**Are there any benefits to participating in the study?**

The research will not benefit you or your child directly. However, by participating in this study we hope to learn more about the types of physical activity that children do. Ultimately, we hope that this research will help to increase physical activity levels in children.
Payment for study participation

Compensation will be provided to you for parking ($3 for each visit to the lab). Children will be compensated for their time with up to $40 in cash. $10 will be given to your child at the end of the first visit to the lab. $20 will be given to your child at the beginning of the 2nd visit to the lab if they return the physical activity monitor and GPS logger in good condition. Finally, your child will receive $10 at the end of the 2nd visit after they complete their questionnaire. If you or your child withdraw from the study before it is completed, your child will get to keep the money they have already received.

Confidentiality and privacy

Every effort will be made to protect (guarantee) your confidentiality and privacy. When we present the research findings we will not include names or any information that can be used to identify you or your child. No one other than the research team will know that you and your child participated in the study unless you tell them. The information we obtain will be de-identified, such that you and your child will receive a unique identification number and will be known by this number, not by name. All of the study data will be entered into password- and firewall- protected computers in the physical activity epidemiology lab, and will be only be available to the research team. We will keep the data here securely for several years, but will never allow anyone other than the research team to have access to the data.

Legally Required Disclosure

Although we will protect your privacy, if legal authorities request information we may be required to reveal it to them (e.g. cases of child abuse).

What if I change my mind about being in the study?

It is important to remember that all aspects of a research study are voluntary. Even after providing consent you and/or your child can withdraw from the study at any time prior to when you submit your final questionnaire responses. In cases of withdrawal, there will be no negative consequences any data you have provided will be destroyed if you want the research team to do so.

How do I find out what was learned in this study?
We expect to have this study completed by the spring of 2017. If you would like a brief summary of the results, please let us know in the consent form below how you would like it sent to you.

Questions about the study

Any questions about study participation may be directed to Dr. Ian Janssen with the contact information listed at the top of this letter. Any ethical concerns about the study may be directed to the Chair of the General Research Ethics Board at chair.GREB@queensu.ca or 613-533-6081.

This study has been granted clearance according to the recommended principles of Canadian ethics guidelines, and Queen's policies.
Physical Activity Levels in Kingston Children

CONSENT FORM FOR PARENT/GUARDIAN – Participant’s copy

I have read the information presented in the information letter about “The Physical Activity and Active Play” study being conducted by Drs. Ian Janssen and Michael McIsaac of Queen’s University. I have had the opportunity to ask questions about my involvement, as well as my child’s involvement, and to receive additional details that I requested. I have been adequately informed of the confidentiality and privacy measures that will be undertaken by the research team to protect my identity and my child’s identity. I understand that if I agree to participate, and provide consent for my child to participate, that we may withdraw from the study at any time. I have been given a copy of this form. I agree to participate in the study and I provide consent for my child to participate in the study.

Signature: ______________________________________

Name of adult participant (Printed) __________________________________

Name of child participant (Printed) __________________________________

Date: _____________________ _______________________________
I have read the information presented in the information letter about “The Physical Activity and Active Play” study being conducted by Drs. Ian Janssen and Michael McIsaac of Queen’s University. I have had the opportunity to ask questions about my involvement, as well as my child’s involvement, and to receive additional details that I requested. I have been adequately informed of the confidentiality and privacy measures that will be undertaken by the research team to protect my identity and my child’s identity. I understand that if I agree to participate, and provide consent for my child to participate, that we may withdraw from the study at any time. I have been given a copy of this form. I agree to participate in the study and I provide consent for my child to participate in the study.

Signature: ____________________________

Name of adult participant (Printed) ________________________________

Name of child participant (Printed) ________________________________

Date: ________________________________

Would you like to receive a summary of the study’s results?

☑ Yes, I would like to receive a summary of the study’s results.

Please send them to this E-mail address: ________________________________

or to this mailing address: ________________________________

☑ No, I do not want to receive a summary of the study’s results.
Would you be willing to be contacted about a potential follow-up study, understanding that you can always decline the request?

☑ Yes. Please contact me by:

Phone: ________________________________
or E-mail: ________________________________
or Mail: ________________________________

☒ No
Appendix C

Ethics Letter of Approval for Thesis
September 26, 2016

Dr. Ian Janssen
Professor
School of Kinesiology and Health Studies
Queen’s University
KHS Building
28 Division Street
Kingston, ON, K7L 3N6

GREB TRAQ #: 6013818
Title: "GPHE-178-14 The Active Play Study"

Dear Dr. Janssen:

The General Research Ethics Board (GREB) has reviewed and cleared your request for renewal of ethics clearance for the above-named study. This renewal is valid for one year from October 17, 2016. Prior to the next renewal date you will be sent a reminder memo and the link to ROMEO to renew for another year. You are reminded of your obligation to submit an Annual Renewal/Closure Form prior to the annual renewal due date (access this form at http://www.queensu.ca/traq/signon.html; click on "Events"; under "Create New Event" click on "General Research Ethics Board Annual Renewal/Closure Form for Cleared Studies"). Please note that when your research project is completed, you need to submit an Annual Renewal/Completed Form in Romeo/traq indicating that the project is 'completed' so that the file can be closed. This should be submitted at the time of completion; there is no need to wait until the annual renewal due date.

You are reminded of your obligation to advise the GREB of any adverse event(s) that occur during this one year period. An adverse event includes, but is not limited to, a complaint, a change or unexpected event that alters the level of risk for the researcher or participants or situation that requires a substantial change in approach to a participant(s). You are also advised that all adverse events must be reported to the GREB within 48 hours. To submit an adverse event report, access the application at http://www.queensu.ca/traq/signon.html; click on "Events"; under "Create New Event" click on "General Research Ethics Board Adverse Event Form".

You are also reminded that all changes that might affect human participants must be cleared by the GREB. For example, you must report changes in study procedures or implementation of new aspects into the study procedures. Your request for protocol changes will be forwarded to the appropriate GREB reviewers and/or the GREB Chair. To submit an amendment form, access the application at http://www.queensu.ca/traq/signon.html; click on "Events"; under "Create New Event" click on "General Research Ethics Board Request for the Amendment of Approved Studies".

On behalf of the General Research Ethics Board, I wish you continued success in your research.

Yours sincerely,

[Signature]

John Freeman, Ph.D.
Chair, General Research Ethics Board

c.: Dr. Michael McIsaac, Co-investigator
Mr. Michael Borghese, Graduate Student
Dr. Lucie Levesque, Chair, Unit REB
Appendix D

Actical Monitor, Location Monitor, and Activity Log Instructions
Instructions for Activity Monitor, Location Monitor, and Sleep & Activity Log

This study will measure your physical activity patterns over one week. In order to do this, we want you to wear an Activity Monitor and a Location Monitor for the next 7 days. We are interested in measuring your normal activity level. Please do not change your normal physical activity levels during the study.

Information and Instructions for the Activity Monitor and Sleep & Activity Log

An Activity Monitor is a small electronic device that records all daily activities as electronic signals. It does not need to be turned on or off. You do not need to change the batteries or recharge this device. Please start wearing the Activity Monitor as soon as your visit to the laboratory is over. We want you to keep wearing it for the 7 days and nights following your visit.

The Activity Monitor should be worn as shown in the picture to the right. You should wear it around your waist using the elastic belt we give you. It should be worn above your right hip. The Active Monitor should be positioned so that “RESPIRONICS” is at the top and “Actical” is at the bottom. It should be located half way between your stomach and back. You can wear it underneath or above your clothes.

It is very important that you wear the Activity Monitor as much as possible. You should take it off when you are having a bath or shower or when swimming since the Activity Monitor is not waterproof. If
there are times that you need to take the Activity Monitor off, other than when having a bath or shower, we would like you to record this on the Activity Monitor and Location Monitor Diary. This should be recorded in the PINK columns of the diary.

We would also like you to keep the Activity Monitor on at night when you go to bed. The Activity Monitor will measure how much you move when you are sleeping. We would like you to record what time you wake up in the morning and what time you go to bed at night on the Sleep, Organized Sports, and Outside Chores Diary. This should be recorded in the YELLOW columns of the diary.

If you participate in organized sports or programs during the study (e.g., hockey, soccer, karate, dance class), we would like you to record these sports and the times you participated in the Sleep, Organized Sport, and Outside Chores Diary. This should be done in the GREEN columns of the diary. Finally, if you do any chores or work outdoors during the study (e.g., shovel snow, farming, cut grass), we would like you to record what time you did this work in the BLUE columns of the diary.

**Information and Instructions for the Location Monitor**

The Location Monitor is an electronic device that connects to satellites and records your location every few seconds. We will use the Location Monitor to determine where you are when you are being active. While you are using the Location Monitor during the study we will not know where you are. However, after the study is over the Location Monitor will tell us where you were throughout the week.

You will wear the Location Monitor on your wrist like a watch. You can wear it on your left or right wrist. You can wear the Location Monitor under long sleeved clothes such as a sweatshirt or coat.

The Location Monitor runs on a rechargeable battery that lasts for about 10 hours. We ask that you charge the Location Monitor tonight before you go to bed. You will need to do this again every night for the following 7 nights. Follow these 4 steps to charge the Location Monitor:

1) Plug the USB end of the charger into the USB adapter.

2) Plug the USB adapter in a regular outlet.
3) Look at the picture to the right. Align the charge posts on the charger with the contacts on the back of the Location Monitor. Then press the charger until it clicks.

4) Leave it plugged in overnight to charge.

You should start wearing the Location Monitor in the morning before you leave your house. On school days, put the Location Monitor on a few minutes before you leave for school. On weekends and holidays, try to put the Location Monitor on at around the same time you would do on school days. Alternatively, if you are leaving your house earlier in the day, put the Location Monitor on before you go.

When you start wearing the Location Monitor each morning, you will need to turn its recording function “on”. Follow these 4 steps:

1) Press the top right button on the Location Monitor. This is button 4 in the picture to the right.

2) Continue pressing this button until the display on the Location Monitor looks like the picture on the bottom right.

3) Press this button once more and the recording function will turn “on”. A large green triangle will appear on the display for 2 seconds immediately after the recording function is turned “on”. Also, the numbers under “Timer” will start to count up. Numbers may also start to appear at the top and bottom of the display once you start to walk around.

4) After the recording function is turned on, you can turn on the watch function by pressing the middle button on the left hand side of the display. This is button 2 shown in the picture above.

Once the recording function is “on”, do not press the top right button of the Location Monitor again. If you do, the recording function will turn “off”. If this happens, press the top right button again to turn it back “on”. You will know the recording function is “on” when the timer in the display is counting up.
Let the recording function of the Location Monitor run continuously each day. The battery on the Location Monitor will usually run out of charge after about 10 hours. Therefore, please try to re-charge the battery for about 15 minutes in the late afternoon or early evening (e.g., right after school, at supper time). After you re-charge the battery for a few minutes, please put the Location Monitor back on and turn “on” the recording function again. Right before you go to bed at night, you should take the Location Monitor off and charge it again for the next day.

*If there are times that you leave home without the Location Monitor, we would like you to record this on the Activity Monitor and Location Monitor Diary.* This should be recorded in the ORANGE columns of the diary.

It is important that you wear the Location Monitor as much as possible when it is turned on. Since the Location Monitor is waterproof, you can wear it when showering, bathing, or swimming. You should not wear the Location Monitor to bed at night as you should be charging it’s battery at that time. If you need to take the Location Monitor off when playing organized sports, please bring it with you to where you are playing. For example, if you need to take it off to play in a basketball game, take it off at the gym and put it back on after the game is over.
Appendix E

Activity Log
# Sleep, Organized Sport, and Outside Chores Diary

<table>
<thead>
<tr>
<th>Day</th>
<th>What time did you get out of bed in the morning?</th>
<th>What time did you go to sleep at night?</th>
<th>If you participated in organized sports or programs, what time did they start and stop?</th>
<th>What organized sports or programs did you participate in?</th>
<th>If you worked or did chores outside, what time did they start and stop?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example</td>
<td>7:30 am</td>
<td>9:30 pm</td>
<td>4:00 pm</td>
<td>karate</td>
<td>7:50 am</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6:30 pm</td>
<td>soccer</td>
<td>8:10 am</td>
</tr>
<tr>
<td>Day 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 2</td>
<td></td>
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<tr>
<td>Day 3</td>
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<tr>
<td>Day 4</td>
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<tr>
<td>Day 5</td>
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<td>Day 6</td>
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<tr>
<td>Day 7</td>
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<td></td>
</tr>
</tbody>
</table>
## Activity Monitor and Location Monitor Diary

<table>
<thead>
<tr>
<th>Day</th>
<th>If you took the Activity Monitor off, what time did you take it off and put it back on?</th>
<th>What were you doing when the Activity Monitor was off?</th>
<th>If you left home without the Location Monitor, what time did you leave and come back home?</th>
<th>Where did you go without the Location Monitor?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example</td>
<td>Time Off 4:00 pm, Time Back On 6:30 pm</td>
<td>karate</td>
<td>Time Left Home 3:45 pm, Time Came Back Home 4:45 pm</td>
<td>Kingston Karate Club</td>
</tr>
<tr>
<td>Day 1</td>
<td></td>
<td>soccer</td>
<td></td>
<td></td>
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<tr>
<td>Day 2</td>
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<td>Day 3</td>
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<td>Day 4</td>
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<td>Day 5</td>
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<tr>
<td>Day 6</td>
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</tr>
<tr>
<td>Day 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix F

Relevant Questions from Child Survey
1. **How often do you eat in a fast food restaurant (e.g., McDonald's, Burger King, Wendy's)?**

   - Never
   - Rarely (less than once a month)
   - About once a month
   - 2-3 times a month
   - Once a week
   - 2 or 3 times a week
   - 4 times a week or more

2. **How many days of the week do you... (Please mark one box for each line)**

<table>
<thead>
<tr>
<th>Days of the Week</th>
<th>0 days</th>
<th>1 day</th>
<th>2 days</th>
<th>3 days</th>
<th>4 days</th>
<th>5 days</th>
<th>6 days</th>
<th>7 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snack while watching TV (including videos, DVDs, YouTube)?</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Snack while working or playing on a computer or games console?</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
Appendix F

Relevant Questions from Parent Survey
1. How would you describe your child's race? Please select all races that are relevant.

- White or Caucasian
- Hispanic or Latin American (e.g., Mexican, Puerto Rican, Brazilian)
- Black or African American (e.g., Kenyan, Jamaican, Somalian)
- Aboriginal or Native (e.g., First Nations, Metis, Inuit)
- Asian (e.g., Chinese, East Indian, Japanese, Vietnamese)
- Arabic / Middle Eastern (e.g., Saudi Arabian, Israeli, Iranian)
- Other race not listed above
- Prefer not to say

2. What is your marital status?

- Married
- Living common-law
- Separated or divorced
- Widowed
- Single and never married
- Prefer not to say

3. During the past 12 months, what was your household income from wages and salaries (before taxes and deductions)?

- Less than $25,000
- $25,000 to $50,000
- $50,001 to $75,000
- $75,001 to $100,000
- More than $100,000
- Prefer not to say
Appendix H

Organized Sport Time Cleaning Protocol
Data Cleaning Guidelines: Organized Sport Times

Before You Start: Things to Keep in Mind
Organized sports are usually strictly scheduled, hence the name “organized” sports. Start and end times are usually set to the hour, or ten or fifteen minutes of the hour (i.e. 9:00, 9:10, 9:15, 9:20, 9:30, 9:40, 9:45, 9:50) due to coaching/referee/field/rink booking times. Therefore, if a participant recorded that they have a soccer game every other day from 6:00 – 7:00 pm, it is likely that they start exactly at 6:00 and end exactly at 7:00, give or take a few minutes. This is unless it is very clear that they deviated from this time, potentially due to factors such as weather conditions, coach/ref arrival times, or overtime. For this reason, it is unlikely that many of the organized sport times will change throughout the verification process. Only obvious oversights and abnormalities will need to be corrected.

When verifying organized sport times, keep in mind the nature of the activity and think about how that activity’s movement would be picked up by the accelerometer. For example, a basketball game usually involves high intensity stop and go movement, so there may be clusters of high intensity movement separated by shorter periods of lower intensity movement/no movement. On the other hand, a hockey game usually involves continuous skating. Since the accelerometers tend to record skating as lower intensity movement, you might see continuous low intensity movement for that game time period.

Organized Sport Time Verification

1. **Ensure that the Sleep Time Verification** has been done for the participant in question before proceeding to step 2.

2. **Obtain the photocopied Sleep and Activity Diary** of the Participant ID you wish to verify non-wear times for. The photocopied Sleep and Activity Diaries are located in the middle filing cabinets within room 501G.

3. **Ensure that you have a coloured pen** to make changes on the photocopied diary. All edits should be made on the photocopy and not on the original diary used by the participant.

4. **Open the Actical 3.10 software on the desktop.**
   a) Click *File*, then click *Open*...
   b) Select and open the .AWC file of the participant ID you are verifying.
   c) Click *Tools*, then click *Actogram*
      - A new screen containing several activity graphs will appear
   d) At the top of the screen above the activity graphs, ensure the *Identity* is the participant ID you are verifying.
   e) Adjust the Scale value on the left hand side of the actogram to 1500.
      - This will change the scale on each y-axis to show a maximum value of 1500, making it easier to observe low-intensity movements
5. **Determine the correct Day 1 date** of the participant you are verifying.
   a) Open the *Database Access* file located in the **Epi-Server ➔ EPI Lab ➔ Database** folder.
   b) Double click and open the *Visit #1* table
   c) In column two, search for the *Date of Visit* of the participant ID you are verifying. **This date + 1** will be the Day 1 date

6. **Verify organized sport start time:**
   a. Identify the first day that organized sport time was recorded. This information will be written in the green columns – “if you participated in organized sports or programs, what time did they start or stop?”
   b. Using the Day 1 date as reference, refer to the Actogram and double click the activity graph corresponding to that date. You will see an **Expanded Actogram**. An example Actogram is shown in Figure 1 below.
   c. Ensure the date on the Expanded Actogram is the correct date of the activity (See **A** on Figure 1 below).
   d. Adjust the *Display Center* (see **B** on Figure 1 below) to match the first recorded organized sport start time, and adjust the *Display Width* (see **C** on Figure 1 below) so that the time range on the x-axis is 1 hour.
   e. There are 2 possible outcomes at this point:
      i. If movement is **present** on the Actogram for the duration of the recorded activity, then we will assume what the participant recorded on the log is correct. Indicate these activity times have been verified and are correct, by placing a check mark beside the start time on the photocopied log. *If there is movement, it is unlikely this time will need to be changed as we cannot be sure that what we are seeing on the Actogram is, or is not, organized sport.*
      ii. If movement is **missing** on the Actogram for the duration of recorded sport time (there are a series of consecutive zero counts), the participant may have removed the device. Refer to the pink columns of the log (“If you took the activity monitor off, what time did you take it off and put it back on at?”) to ensure the non-wear time is documented there. If it is not, write it in. **Remember that organized sports are not composed entirely of vigorous activity, and that some sedentary activity might be registered by the Actical. If this is the case, do not indicate this in the non-wear column. We only want to record times where it is obvious the device has been removed (20+ minutes of zero counts).**
7. Verify Organized Sport end time:
   a. Using the same organized sport period that was used in Step 6, scroll forward in time using the Display Centre tool, until you reach the end time of the sport period. There will be two options:
      i. If movement is present around this end time, we will assume the recorded time is correct. If this is the case, indicate that the end time has been verified, and is correct, by placing a check mark next to the recorded end time on the photocopied log.
      ii. In certain situations, you will see a repeated pattern of movement throughout the recorded activity, and this pattern may extend beyond the end time. In this case, it may be tempting to extend the end time of the recorded activity. Keep in mind, however, that these movements may be attributable to things like playing after practice – we cannot be sure that the participant was incorrect. If this pattern extends only slightly beyond the recorded end time, then assume the end time is correct and place a check mark beside the recorded end time on the photocopied log. If this pattern of movement extends far beyond the end time (i.e., an hour or more) then more investigation may be required. If this is the case, please let Emily, Mike or Chao know and they will make any adjustments needed.

   Three illustrative examples for verifying get-up times can be found in Examples 1-3 on pages 5-7.

8. Repeat Steps 6-7 for the remaining organized times recorded in the diary. Ensure each start/end time has been verified before moving onto another participant.
Note: if you are not sure of the times you have corrected, make a note of this in the “Issues occurred?” column of the tracking sheet. Please get a second opinion (ideally from Chao, Mike, or Emily) on this issue. The data should not be entered into database (Step 9) until the issue has been resolved.

9. Indicate that all Organized Sports Times has been verified and corrected on the data cleaning tracking sheet pinned on the bulletin board in Room 501G. Every time you have completed all the sleep time, organized sports time, and non-wear time verification and correction for a same day of a participant’s, put a check mark in the corresponding day in the “All 7 days verified & corrected?” column. **The next time you start working on the data verification you should pick-up where you left off with this participant.**

10. Enter Corrected Organized Sport Information into Database
   a) All of the organized sports time information for all 7 days for the participant ID, including data on the diary that was accurate and data that was corrected, should be entered in the electronic study database. This should be entered in the “Sleep and Activity Diary Day [1-7] – Cleaned” table in the Database-Cleaned Access file located in the Epi-Server ⇒ EPI Lab⇒ Database folder.
   b) Enter your name in the Researcher Name column beside the participant ID in the Database – Cleaned Access file.

11. Indicate that all verified and corrected data on the data cleaning tracking sheet pinned on the bulletin board in Room 501G. Every time you have entered all the verified and corrected sleep times, organized sports times, and non-wear times for a same day of a participant, put a check mark in the corresponding day in the “All data entered into database?” column. **The next time you start working on the data entry you should pick-up where you left off with this participant.**
Appendix I

In Town Trips Cleaning Protocol
In Town Trips Protocol – Active Play Study

This protocol is to be completed after the “PALMS protocol – active play study,” the “CSV GPS cleaning protocol – Active play study” and the “CSV GPS cleaning – Out of Town data.” Before beginning, check the tracking sheet on the bulletin board in room 501G to ensure the “CSV GPS cleaning – Out of Town data” protocol has been completed for the participant in question. Enter your name on the tracking sheet pinned on the bulletin board in Room 501G for the “In Town Trips Protocol” each time you start a new participant. The purpose of this protocol is to:

- Remove false trips that were incorrectly identified by PALMS
- Determine the starting location and final destination of each trip, and
- Confirm the mode of travel for imputed trips (e.g., pedestrian, bicycle, vehicle)

1. Open the Access file entitled “Database” with the participant’s Visit #1 date from the following location: \\192.168.1.100\EPI Lab\Database\Main Study\Database.accdb
   a. Determine the Day 1 date. It will be the day after Visit #1
   b. Determine which season in which the data was collected and whether the participant was in school at that time

2. Obtain the participant’s log
   a. Determine which day of the week corresponds with Day 1

3. Open the Access file entitled “Participant home + School Coordinates” with the participant’s home address and school address from the following location: \\192.168.1.100\EPI Lab\GIS
   a. Enter the coordinates of the home and school location into Google Maps’ directions feature with a comma between latitude, longitude to become familiar with those locations
   b. If the walking directions between home and school take less than 3 minutes, PALMS may not identify these trips. In this case, follow the instructions in Appendix C after completing this protocol.

4. Open the CSV file of interest from the following location: \\192.168.1.100\EPI Lab\PALMS exports\CSV. Note that the CSV file names correspond to the participant ID numbers.
   a. Select the view tab in excel, and select freeze panes, “freeze top row”.
   b. Highlight and copy column “tripNumber,” right click beside the “tripNumber” column and select “insert copied cells.” Rename the old column “tripNumber_old.” All subsequent work in this protocol will be done on the new
“tripNumber” column and the data in the “tripNumber_old” column should not be changed.

c. Highlight and copy column “tripMOT,” right click beside the new “tripNumber” column and select “insert copied cells.” Rename the old column “tripMOT_old.” All subsequent work in this protocol will be done on the new “trip_MOT” column and the data in the “tripMOT_old” column should not be changed. “Trip_MOT” refers to the modality of the trip:

1. -1 – unknown (i.e., No GPS data)
2. 0 – stationary
3. 1 – pedestrian
4. 2 – bicycle
5. 3 – vehicle

d. Create three more columns to the right of the “tripMOT” column. Label these columns “tripStart,” “tripEnd” and “Imputed.” Insert 0’s for each row in these columns from the start of the file to the end of the file.

5. Open the corresponding Fusion Table for the participant from the activeplayfusiontables@gmail.com google drive (password: Epidemiology). It will labelled “0ID_imputed.” For instance, for participant ID 123 this table would be labelled “0123_imputed”. These are the colours and their corresponding activity levels:
   a. Blue – sedentary (activity intensity = 0)
   b. Yellow – light physical activity (activity intensity = 1)
   c. Green – moderate physical activity (activity intensity = 2)
   d. Red – vigorous physical activity (activity intensity = 3)

6. On the Google Fusion table, go to the “Map” tab. On the top left of the Google fusion table, click “Filter” and select by “tripNumber”

7. In the Google fusion table, Enter “1” in both boxes of the tripNumber filter. In the Excel spreadsheet, select the “tripNumber_old” column and hit “Ctrl + F” on the keyboard. Enter 1 into the box and press “Find Next”. You may have to click on “options” and select “match entire cell contents”.

   a. First, look at the Google fusion table evaluate whether this is a valid trip. A trip is valid if it is from one location to another either via vehicle or by active transportation (see Appendix D Figures 1 and 2). An example of a trip that is not valid would be activity that occurs solely within a location such as the school yard or a building (see Appendix D Figure 3). If the trip is invalid, replace the number in the “tripNumber” column with “-2” and skip steps b-d.

   b. Next, make sure the trip has not been cut short or extended or PALMS did not miss a destination. A trip consists of linear motion from one location to another. If a trip does not appear to have a rational starting point and end point (ie. a road) or
there appears to be clustering of points at the beginning or end of the trip (see Appendix D Figure 4), identify the time of each trip and filter the fusion table by “datetime” using the format dd/mm/yyyy h:mm am/pm (e.g., 22/01/2016 5:03 PM) to show an additional 10 minutes before and after each trip. **The trip we want to identify is the duration of linear movement from one location to another.** You can also look at the “activity” counts in the CSV file to determine when a consistent pattern of movement starts or ends. Ensure that the trip number is the same for the duration of this time, extending or shortening a trip as necessary.

A trip may begin and end at the same location. Some of these trips have no destination, such as a walk around the neighbourhood. **This is a valid trip.** However, some of these trips have a destination, such as a trip to a fast food drive thru or dropping another person off, that would not be identified by PALMS if there was a very short pause at the destination. **These trips need to be split into 2 trips.**

When participants take the bus to school, PALMS may split the walking and bussing portions up or only count them as 1 trip (see Appendix D Figure 5). **These trips need to be split into 2 trips.** In cases where there is a pause point in a trip to another destination (e.g., dropping someone off at the movie theatre or going through the Tim Hortons drive thru on the way to hockey practice), the trip does NOT need to be modified to reflect that pause point. **Do NOT combine trips. If you are unsure, ask.**

**To extend or shorten a trip:**
- filter by “datetime” using the format dd/mm/yyyy h:mm am/pm (e.g., 22/01/2016 5:03 PM).
- Ensure that for the duration of the trip identified on the Google Fusion table, the trip number is the same.
- **If shortening a trip,** replace the trip number for the removed epochs with “-2”. Trips should be shortened if:
  - There is walking at the end of a vehicle trip (i.e., walking from the car to the store through the parking lot)
  - There is clustering of movement at either end of the trip (i.e., playing in the school yard after arriving to school)
- **If lengthening a trip,** replace the value of “0” or “-1” with the number assigned to that trip and extend the “tripMOT” value to match the rest of the trip. Trips should be lengthened if:
  - PALMS cut the trip short, identified by filtering by date time around trips that do not have rational start and end points
To create a return trip or split a trip into 2 parts: (RECALL this is ONLY done when it is a round trip with a pause point such as a restaurant or store that was not captured by PALMS, OR when breaking up walking to the bus stop and taking the bus to school)

- Identify the epoch that corresponds to the start of the second portion of the trip
- For this and subsequent epochs involved in that trip you will need change the trip number to “1 + the highest trip number so far”.
- For instance, if the highest trip identified to date was 53, the return portion of this trip would be identified as trip 54. The highest trip number can be identified by the number under the tripNumber filter in the Google Fusion table or by searching for the MAX value in the “tripNumber” column.
- In the case of participants taking the bus to school, ensure the walking trip has a “tripMOT” of 1 (pedestrian) and the vehicle trip has a “tripMOT” of 3 (vehicle).

c. Finally, identify where the trip starts and finishes. In the Google Fusion table, click on the first and last point in the trip to see at what time the trip occurred and determine the direction of the trip.

d. The trip start and end locations should fall under one of the categories listed immediately below this paragraph. A more complete explanation of these destinations is provided in Appendix A after the list. In the “tripStart” column, replace the 0’s that correspond to the time of trip number 1 with the number that corresponds to the starting location. In the “tripEnd” column, replace all of the 0’s that correspond to the time of trip number 1 with the number that corresponds to the ending location. You may need to look at a participant’s log or examine the 10 minutes before or after the trip to help identify locations (i.e., especially to differentiate between park use for recreation vs. organized sport purposes, or identifying trips for chores or work purposes). Use Google satellite view and Google street view frequently when determining locations! If the trip happens to occur over water, change the “tripMOT” to 4 (active boating) for trips identified as pedestrian or 5 (passive boating) for trips identified as vehicle. Drag down the “tripMOT” column to ensure that the tripMOT is consistent for the duration of the trip (i.e., no stationary time within a pedestrian trip).

Location numbers are as follows (see Appendix A for more details):

1. Participant’s home (or the homes that they typically sleep at if they live at multiple homes)
2. Another home
3. Bus stop (i.e., where the participant is picked up by the school bus)
4. Participant’s school to go to class at school (i.e., to/from school at the beginning/end of the school day)
5. Participant’s school for other trips occurring during school day (e.g., field trip, going home for lunch, doctor’s appointment, gym class at location off school grounds)
6. Participant’s school for trips occurring outside of school hours for non-class purposes (e.g., to play in school playground on weekend, to go to school activity in evening)
7. Another school, including the building and school grounds
8. Developed park/greenspace (e.g., park or greenspace area developed and maintained by the city)
9. Undeveloped greenspace (e.g., field, wooded area)
10. Conservation area or Provincial Park (e.g., Lemoine Point Conservation Area, Cataraqui Creek Conservation area, Grass Creek Park)
11. Government or school owned recreation facility for physical activity participation. Use the participant’s log, Google satellite view and look at “activity” to identify if they are participating in organized sport at this time (e.g., going to arena, soccer field operated by Kingston, or Queen's ARC to play sport)
12. Government or school owned recreation facility for other purposes. Use the participant’s log, Google satellite view and look at “activity” counts to identify if they are participating in organized sport at this time (e.g., going to arena to watch a hockey game)
13. Commercial recreation facility for physical activity participation. Use the participant’s log, Google satellite view and look at “activity” counts to identify if they are participating in organized sport at this time (e.g., Dance studio, gymnastics club, YMCA, golf course)
14. Commercial recreation facility for other purposes. Use the participant’s log, Google satellite view and look at “activity” counts to identify if they are participating in organized sport at this time
15. Retail: big box stores (e.g., Walmart, Loblaws, Canadian Tire)
16. Retail: downtown shops (e.g., The Gap, Lululemon)
17. Retail: strip mall or stand-alone store not meeting big box store criteria (e.g., strip mall at Division/Concession, Shoppers Drug Mart at 1875 Bath Rd.)
18. Retail: shopping mall (Cataraqui Town Centre, Frontenac Mall)
19. Restaurant: fast food (e.g., McDonald’s, A&W, Wendy’s, Harvey’s, Pizza Pizza, Subway)
20. Restaurant: full service (e.g., The Keg, Milestones, Lone Star)
21. Restaurant: coffee/donut focus (e.g., Tim Horton’s, Starbucks)
22. Restaurant: other, desserts but no meals available (e.g., Menchies, Mio Gelato)
23. Convenience stores and gas stations
24. Entertainment or cultural facility (e.g., Movie theatre, museum, art gallery)
25. Church or other place of worship
26. Community centre
27. Library
28. Health care facility (e.g. doctor’s office, dentist, hospital, optometrist)
29. Round trip (e.g. leisure walk or drive that starts and ends in the same location with no particular destination)
30. Work/chores related destination (e.g., paper route)
31. Transport within the context of outdoor play (e.g., >1 relatively short pedestrian and/or bicycling trips identified within a few minutes of each other with clusters of outdoor movement before, in between, and typically after the trips)
32. Boating or water sports
33. Other
34. Unknown
35. Transit stop (e.g., city bus stop, subway station, ferry terminal)

8. Next complete step 7 for each trip with valid GPS data. Proceed to step 9 when working with imputed trips. Imputed trips will appear as a single point on the road. The highest trip number can be identified under the tripNumber filter in the Google Fusion table.

9. This step is to clean trips that have been imputed, this means the values in the “lat_old” and “lon_old” columns will be -180. These trips will show up as a single point on the Google Fusion table. In the “Imputed” column please change the “0” to “1” for all imputed trips, even trips that have been partially imputed (i.e., the watch died along the route).

   a. For the first imputed trip, identify where the trip starts and finishes. To do this you will need to examine time before and after the trip. Locations before and after the trip may also be single points. Click on these points to determine which is the beginning and the end of the trip. Looking at the participant’s log may also be useful in determining start and end locations. Change the values of the “tripStart” and “tripEnd” columns for the duration of the trip as per the location codes in Step 10. In the “Imputed” column please change the “0” to “1” for all imputed trips.
   
   b. Then, look at the “tripMOT” variable. Trip mode may or may not have been imputed when adding the trip. The following numbers correspond to the following modes of transportation:

   • -1 – unknown (i.e., No GPS data)
   • 0 – stationary
   • 1 – pedestrian
• 2 – bicycle
• 3 – vehicle
• 4 – active boating
• 5 – passive boating

i. Ensure that the tripMOT corresponds with the appropriate method of transportation based on intensity, duration and season (i.e., there is not likely to be a lot of cycling during the winter). It may also be useful to look up directions between the two points in Google Maps and at the duration of the trip in the CSV file and determine if that time is approximately an appropriate travel time for that mode of transport.

1. A “tripMOT” of 1 (pedestrian) should correspond with speeds of 1-10 km/h in any season and a consistent activity pattern greater than 375 counts. Some counts between 100 and 375 may occasionally be present and some stops may occur (i.e., at a red light). Generally, walking will consist of several consecutive minutes of moderate intensity.

2. A “tripMOT” of 2 (bicycle) should correspond with speeds of 10-24.9 km/h in the spring, summer and fall seasons and a more variable activity count profile. Activity counts may range from approximately 25 - 1000, with a sporadic pattern. Cycling typically does not contain counts in the vigorous range (i.e., > 1625 per 15s epoch), but will fluctuate between sedentary, light, and moderate.

3. A “tripMOT” of 3 (vehicle) should correspond with speeds greater than 25 km/h in any season, most activity counts being <25 per 15s epoch, with some light activity counts. Occasionally trips on school buses will contain more counts in the light range and some in the moderate range, but the speed will still be high enough to denote this trip as being in a vehicle. It is highly unlikely that counts in the vigorous range would occur while using passive transportation.

4. A “tripMOT” of 4 (active boating) refers to any trips over water that have been identified as pedestrian or bicycle. This would correspond with water activities such as kayaking, canoeing or paddle boarding.

5. A “tripMOT” of 3 (passive boating) refers to any trips over water that have been identified as vehicle. This would correspond with travelling over water in a motor boat.

ii. If the “tripMOT” appears to be incorrect, replace those values with the appropriate number.
10. In the Google fusion table, Enter “-1” in the both boxes of the tripNumber filter. This will give all the remaining imputed locations. If there are any imputed points on a road insert a new trip number for this participant in the “tripNumber column” for the duration of the trip (the highest value so far can be found in the Excel spreadsheet or in the Google fusion table under the trip number filter boxes – add one to this number). Complete step 9a. and 9b. for these trips.

11. As a final check, highlight all columns, select the “data” tab in excel and select “filter”. Use the dropdown arrow to filter the “tripNumber” column to show all trips >0 (i.e., de-select -2, -1 and 0). Using the dropdown filters for the tripNumber, tripMOT, tripStart, tripEnd columns, ensure that these other columns contain logical values – for instance, that tripMOT does not equal -1 (all trips must have a mode), that both tripStart and tripEnd do not equal 0, and that the imputed trips are indicated with a 1.

12. Once you have completed all of the steps, check off that the participant has been completed on the “In Town Trips Protocol” pinned to the bulletin board in Room 501G.