RECOMMENDATIONS FOR MINIMAL AND OPTIMAL AMOUNTS OF PHYSICAL ACTIVITY TO REDUCE THE RISK OF DYSLIPIDEMIA IN YOUTH

by

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ABSTRACT

Background: Physical inactivity has been consistently associated with numerous negative health outcomes that track from childhood into adulthood, making physical activity a special concern in the pediatric population. Dose-response studies are particularly useful when trying to understand the minimal and optimal amounts of physical activity needed to reduce the risk of negative health outcomes. Unfortunately, previous work within youth has relied on self-reported measures of physical activity, and this research does not provide a clear picture of the true relation between physical activity and health.

Objectives: Manuscript 1. Describe the dose-response relation between dyslipidemia and moderate-to-vigorous physical activity (MVPA) in youth. Manuscript 2. Quantify the difference between self-reported and objectively measured MVPA in youth. Taken together, the overall objective of this thesis was to examine the dose-response relation between objectively measured MVPA and dyslipidemia in youth and determine how this may affect current Canadian physical activity guidelines.

Methods: Both manuscripts used data from the U.S. National Health and Nutrition Examination Survey. Fractional polynomial regression modeling was used to fit the dose-response curves between MVPA and lipid/lipoprotein measurements. Regression analysis as well as a Bland-Altman plot was used to explain the discrepancy between
self-reported and objective measures of MVPA. All analyses were completed using SAS statistical software.

**Results:** *Manuscript 1.* Risks for high-risk HDL-cholesterol and triglyceride values decreased in a curvilinear manner with increasing minutes of MVPA. The greatest reduction in risk occurred within the first 30 min/d of MVPA. The relation between level of MVPA and LDL-cholesterol was unclear. *Manuscript 2.* The average youth over-reported their MVPA by ~30 min/d. The over-reporting was not mediated by basic demographic factors; however, the difference in reporting was systematic in nature such that inactive youth over-reported to the greatest extent.

**Conclusions:** *Manuscript 1.* Youth need to accumulate 30 min/d of MVPA to greatly reduce their risk for dyslipidemia. *Manuscript 2.* Youth tend to over-report their daily MVPA by approximately 30 min/d. Combined, the results from this thesis suggest that physical activity recommendations for cardiovascular health in youth should suggest a minimum of 30 min/d of MVPA and preferred level of 60 min/d.

**Key Words:** moderate-to-vigorous physical activity, dose-response, lipids/lipoproteins, self-report, accelerometer, youth
CO-AUTHORSHIP

This thesis presents the work of Allana LeBlanc in collaboration with her supervisor Dr. Ian Janssen.

**Manuscript 1.** *Dose-response relation between physical activity and dyslipidemia in youth.* The idea of using the National Health and Nutrition Examination Survey to examine the dose-response relation between physical activity and dyslipidemia in youth was that of Dr. Janssen. The statistical analysis, interpretation of results, and writing of the manuscript was completed by Allana LeBlanc under the supervision and with editorial comments provided by Dr. Janssen. This manuscript has been submitted to and is presented as requested by the *American Heart Journal.*

**Manuscript 2.** *Difference between self-report and objectively measured moderate-to-vigorous physical activity in youth.* Again, Dr. Ian Janssen provided the idea to use the National Health and Nutrition Examination Survey to examine the relation between self-reported and objectively measured physical activity in youth. Statistical analysis, interpretation of results, and writing of the manuscript was completed by Allana LeBlanc under the supervision and with editorial comments provided by Dr. Janssen. This
manuscript has been submitted to the *British Journal of Sports Medicine* and is presented as requested by the journal.

The Introduction, Review of Literature, General Discussion, and Appendices were completed by Allana LeBlanc with suggestions and editorial comments from Dr. Janssen.
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TABLE OF CONTENTS

Abstract ................................................................................................................................................. ii

Acknowledgements ............................................................................................................................... vi

Table of Contents ................................................................................................................................... vii

List of Abbreviations ............................................................................................................................. x

List of Figures .......................................................................................................................................... xi

List of Tables ............................................................................................................................................ xii

CHAPTER 1 .............................................................................................................................................. 1

1.1 Overview .......................................................................................................................................... 1

1.2 Objectives and hypotheses ............................................................................................................... 3

1.3 Thesis organization .......................................................................................................................... 4

1.4 References ....................................................................................................................................... 5

CHAPTER 2: Review of literature ........................................................................................................... 7

2.1 Overview and outline ......................................................................................................................... 7

2.2 Health benefits of physical activity in children and youth .............................................................. 7
   2.2.1 Physical activity and psycho-social health ................................................................................. 8
   2.2.2 Physical activity and bone health ............................................................................................. 9
   2.2.3 Physical activity and obesity .................................................................................................... 10
   2.2.4 Physical activity and blood pressure ....................................................................................... 11
   2.2.5 Physical activity and dyslipidemia ............................................................................................. 12
## LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CI</td>
<td>Confidence interval</td>
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<tr>
<td>CVD</td>
<td>Cardiovascular disease</td>
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<td>HDL</td>
<td>High-density lipoprotein</td>
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<td>LDL</td>
<td>Low-density lipoprotein</td>
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<td>METs</td>
<td>Metabolic equivalents</td>
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<td>MetS</td>
<td>Metabolic syndrome</td>
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<td>MVPA</td>
<td>Moderate-to-vigorous physical activity</td>
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<tr>
<td>NHANES</td>
<td>National Health and Nutrition Examination Survey</td>
</tr>
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<td>OR</td>
<td>Odds ratio</td>
</tr>
<tr>
<td>PA</td>
<td>Physical activity</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

Figure 2.1 Risk ratios for hypertension in relation to minutes of moderate-to-vigorous physical activity ................................................................. 12

Figure 2.2 Possible dose-response patterns between physical activity and health....... 20

Figure 3.1 Odds ratio for high-risk LDL-cholesterol values (Panel A), high-risk HDL cholesterol values (Panel B), and high risk triglyceride values (Panel C) according to moderate-to-vigorous physical activity ................................................................. 56

Figure 4.1 Difference between self-reported and accelerometer measured moderate-to-vigorous physical activity in boys, girls, and for the total sample ......................... 80

Figure 4.2 Difference between self-reported and accelerometer measured moderate-to-vigorous physical activity according to age and race................................................................. 82
LIST OF TABLES

Table 2.1 Summary of research comparing accelerometer and self-reported measures of physical activity in youth ................................................................. 25

Table 3.1 Descriptive characteristics of participants ................................................................. 52

Table 3.2 Descriptive dietary characteristics of participants ......................................................... 52

Table 3.3 Descriptive information for LDL-cholesterol, HDL-cholesterol, and triglycerides measures ................................................................................................................................. 54

Table 3.4 Adjusted odds ratios for the relation between covariates and unfavourable lipid/lipoprotein levels in relation to physical activity ................................................................. 55

Table 4.1 Descriptive characteristics of subjects ........................................................................ 73

Table 4.2 Summary of moderate-to-vigorous physical activity measures .......................... 78
CHAPTER 1

INTRODUCTION

1.1 Overview

Within children and youth a physically active lifestyle is associated with a decreased likelihood of overweight and obesity, an increased positive self-concept, a decreased likelihood of suffering from depression and anxiety, and a more favourable risk factor profile for cardiovascular disease including higher levels of high-density lipoprotein cholesterol and lower triglyceride levels.

Physical inactivity is of special concern in the pediatric population since it has been reported that physical activity habits and skills acquired during childhood and adolescents are predictive of a person’s activity habits later in life. The benefits of physical activity in adulthood have been well documented and include a reduction in the risk of all-cause mortality, fatal and non-fatal cardiovascular disease, certain types of cancer, osteoporosis, and type 2 diabetes.

Although it is well established that physical activity has a beneficial effect on the health and well-being of children and youth, what is not well understood is the specific volume or dose of physical activity that is required. The research in this thesis aims to describe the dose-response relationship between moderate-to-vigorous physical activity (MVPA) and plasma lipid/lipoproteins in youth. Plasma lipids are key risk factors for...
cardiovascular disease, the leading cause of death in Canada. Although the clinical manifestation of cardiovascular disease does not typically occur until adulthood, there is evidence that the process of atherosclerosis begins at a very young age and that elevated cardiovascular disease risk factors track from adolescence into adulthood.9,10

Once the appropriate dose of physical activity required for good health is established, this needs to be conveyed into a public health message, such as physical activity guidelines. The goal of these guidelines is to help the population achieve the desired level of physical activity. These guidelines should be developed in a way that considers both the true dose of physical activity that is needed, as well as any misinterpretations individuals may have about their own levels of activity. That is, if in reality youth need to accumulate 30 minutes of MVPA per day for good health, the public health messages may need to recommend a higher volume due to differences in perceived and actual levels of MVPA in children and youth. Self-reported physical activity is commonly over-reported either through misunderstanding of what constitutes moderate-to-vigorous physical activity or by social desirability bias. It is therefore important to understand the relation between self-reported and objective measures of physical activity.
1.2 Objectives and hypotheses

*Manuscript 1.* To determine the dose-response relationship between MVPA and plasma lipids and lipoproteins in youth. The lipids/lipoproteins examined include those that are commonly measured in the clinical setting: low density lipoprotein (LDL) cholesterol, high density lipoprotein (HDL) cholesterol, and triglycerides. It was hypothesized that MVPA is: 1) negatively related to triglycerides levels in a linear manner, 2) positively related to HDL-C in a curvilinear manner such that the largest changes in HDL-C will occur at the lower end of the physical activity spectrum, and 3) negatively related to LDL-C in a curvilinear manner such that significant changes in LDL-C will not be observed until the upper end of the physical activity spectrum.

*Manuscript 2.* To examine the relation between self-reported and objectively measured MVPA. Specifically, the objectives will be to: 1) to quantify the magnitude of the difference between self-reported and objectively measured MVPA in youth, 2) to determine if the difference between self-reported and objective measures varied across the MVPA spectrum, and 3) to determine if this difference was influenced by demographic characteristics (sex, age, ethnicity). It was hypothesized that: 1) youth would over report the amount of time they spent engaging in MVPA, 2) the magnitude of the difference between self-reported and objectively measured MVPA would be larger at the lower end of the physical activity spectrum such that inactive youth would over-report their MVPA to the greatest extent, and 3) the magnitude of the difference
between self-reported and objective measures would vary by demographic characteristics.

1.3 Thesis organization

This thesis conforms to the regulations outlined in the Queen’s School of Graduate Studies and Research “General forms of theses”. Chapter 2 provides the reader with a review of the current literature in the area of physical activity and health in youth, with an emphasis placed on the dose-response nature of the relations. Furthermore, this review focuses on the discrepancies between self-reported and objectively measured physical activity in youth. Chapter 3 contains the first manuscript entitled “Dose-response relation between physical activity and dyslipidemia in youth”. This manuscript has been submitted to the American Heart Journal and is formatted according to the requirements of that journal. Chapter 4 contains the second manuscript “Difference between self-reported and accelerometer measured moderate-to-vigorous physical activity in youth”. This manuscript has been submitted (with revisions) to the British Journal of Sports Medicine and is formatted accordingly. Chapter 5 contains a general discussion that covers the strengths and limitations, public health and policy implications, future directions, and overall conclusions of the thesis.
1.4 References


CHAPTER 2

REVIEW OF LITERATURE

2.1 Overview and outline

The purpose of this literature review is to discuss the health benefits of physical activity in school-aged children and youth, with special consideration given to the dose-response relation between physical activity and health. The literature review starts by providing a brief overview of the health benefits of physical activity in children and youth. It then provides an overview of the current physical activity level of Canadian children and youth in relation to national and international physical activity guidelines. The review then highlights the available evidence on the dose-response relation between physical activity and health in children and youth. The final section of the literature review examines the difference between self-reported and objectively measured physical activity in youngsters. This review aims to highlight some of the major gaps in the current literature, particularly around research that is needed to improve public health guidelines for physical activity in school-aged children and youth.

2.2 Health benefits of physical activity in children and youth

Physical activity is defined as “any bodily movement produced by skeletal muscle that results in energy expenditure”.¹ It is well established that high levels of moderate-
to-vigorous intensity physical activity are associated with positive health benefits in people of all ages.\textsuperscript{12-14} This section (section 2.2) summarizes and expands upon the findings from two recent systematic reviews that examined the health benefits of physical activity in school-aged youth.\textsuperscript{2,3} Both of these systematic reviews were completed by a large and multidisciplinary group of experts in the pediatric exercise sciences field, and culminated in the publication of evidence-based consensus reports. The MSc candidate (Allana LeBlanc) also participated in the generation of a similar systematic review that was recently completed as part of Canada’s physical activity guidelines project,\textsuperscript{4} and the content in this section is also based on that review.

\subsection*{2.2.1 Physical activity and psycho-social health}

Common indicators of mental health include anxiety, depression, self-concept, and self-efficacy.\textsuperscript{2,3} The burden of these indicators has been understudied in youth and the lack of longitudinal studies examining mental health provide no evidence that mental health issues track from childhood to adulthood.\textsuperscript{2} However, there seems to be a general consensus that physical activity is ‘inherently good’ with respect to self-esteem, mood, and cognitive functioning.\textsuperscript{5} The quality of evidence is limited considering that only 12 studies have examined the relation between physical activity and mental health in children and youth.\textsuperscript{2} However, the consistency across studies is high, with all published studies reporting an inverse association between physical activity and depressive symptoms and anxiety.\textsuperscript{2} A positive association was also consistently seen
with self-esteem, self-concept, and academic performance.\textsuperscript{2,3} However, it is important to note that previous research is primarily based on observational cross-sectional studies.\textsuperscript{2} Because of the varying methodologies used in the different studies, and an insufficient number of intervention studies, it is impossible to make any conclusions about the causality of associations and the dose-response patterns between physical activity and mental health.\textsuperscript{2}

\textbf{2.2.2 Physical activity and bone health}

Peak bone mass is accrued during adolescence and maximizing bone development is a key factor in the prevention of osteoporosis later in life.\textsuperscript{5} It has been suggested that there is a ‘window of opportunity’ during early pubertal years for the greatest increase in bone mineralization.\textsuperscript{2} During this period, youth accumulate as much as 25\% of their final adult bone mass.\textsuperscript{5} The greatest bone mineralization is seen in highly active youth,\textsuperscript{2} with weight bearing exercise accounting for a 2 to 30\% increases in bone mineral density.\textsuperscript{5} Intervention trials have shown that weight bearing activities (e.g., jumping or weight lifting) are effective in increasing bone mineral density in both children and adolescents.\textsuperscript{5} The osteogenic effect of physical activity on bone mineral density is often site-specific and related to the type of activity the individual is engaging in.\textsuperscript{3} Past research suggests that children and youth should engage in weight-bearing activities on 3 or more days per week. This recommendation is primarily based on the
frequency of participation in the various intervention studies, and there is a limited amount of information regarding any possible dose-response relationship.  

### 2.2.3 Physical activity and obesity

Overweight and obesity are generally measured through the calculation of a person’s body mass index (BMI). Although there are many limitations associated with BMI, it is easy to administer and extremely feasible for population based research. To account for variations that are associated with age, sex, and maturation; sex-specific BMI growth curves have been developed for the pediatric population.  

Obesity is considered the second highest cause of preventable death in the world and is associated with numerous chronic diseases such as heart disease, stroke, type 2 diabetes, osteoarthritis, and some forms of cancer.  

In Canada, the proportion of youth considered to be overweight or obese is over 20%.  

Cross-sectional and prospective observational studies have shown, with good consistency, that physical activity in children and youth is associated with a decreased likelihood of overweight and obesity.  Experimental research has shown that moderate intensity aerobic exercise programs, when performed for 30-60 minutes per session on 3-7 days of the week, can lead to a reduction in BMI and body fat within overweight and obese youth.  However, there is no consistent dose-response pattern between studies, which makes it challenging to accurately describe the dose-response relationship.
2.2.4 Physical activity and blood pressure

Elevated blood pressure in childhood leads to increased risk of hypertension as an adult. The available evidence suggests that increasing physical activity does not have a positive effect on blood pressure for children and youth who already have favourable blood pressure levels. However, the results from both intervention and observational studies suggest that physical activity is effective in managing blood pressure within youth with hypertension and pre-hypertension. A dose-response relationship has been described in youth with the likelihood of hypertension decreasing in a curvilinear manner with increasing minutes of moderate-to-vigorous intensity physical activity (Figure 1), suggesting that even modest amounts of physical activity can have important effects on hypertension in youth. Results from intervention studies suggests that at least 30 minutes of physical activity on 3 days of the week, when performed at minimal intensity of 80% maximum heart rate, is needed to reduce blood pressure in youth with hypertension.
Figure 2.1  Odds ratios for hypertension in relation to volume of moderate-to-vigorous physical activity. Solid lines represent the predicted relationship between moderate-to-vigorous physical activity and hypertension for a 12 year old non-Hispanic white male. Dashed lines represent 95% confidence intervals. Taken from Mark and Janssen.9

2.2.5 Physical activity and dyslipidemia

Although the clinical manifestations of cardiovascular disease do not typically occur until later in life, it is now clear that the process of atherosclerosis begins in childhood.8,10,11 Blood lipid and lipoprotein levels (e.g., cholesterol, triglycerides) in childhood are related to markers of atherosclerosis12 and an abnormal lipid profile in adulthood.8,13,14 Lipids/lipoproteins typically considered in the clinical setting include low-density lipoprotein (LDL) cholesterol, high-density lipoprotein (HDL) cholesterol, total cholesterol, and triglycerides. The utility and measurement of these markers are covered in more detail in Appendix A. Briefly, increased levels of HDL-cholesterol (‘good’ cholesterol) and decreased levels of LDL-cholesterol (‘bad’ cholesterol) and triglycerides are associated with decreased likelihood of developing atherosclerosis and
cardiovascular disease. This relationship is true across all age groups and has been shown to track from childhood into early adulthood. Therefore, the prevention of dyslipidemia in the early years of a person’s life is a special concern.

Physical activity is an important component of the therapeutic lifestyle changes recommended for preventing and treating dyslipidemia in children and youth. Past work has established that physical activity is positively associated with HDL-cholesterol and negatively associated with triglyceride levels within children and youth. The relationship between physical activity and LDL-cholesterol is less clear. There has been some evidence that exercise training decreases LDL-cholesterol in youth, but several studies have not reported these effects.

It is believed that physical activity elicits the greatest changes in lipid levels in those with high-risk values. High-risk values for lipids and lipoprotein levels are different for youth than for adults and age- and gender specific cut-points have been developed to explain differences that occur with natural growth and maturation (Appendix B). It has been suggested that youth may need to engage in sustained amounts of moderate-to-vigorous physical activity to induce and maintain any change in their lipid/lipoprotein profile but any specific dose-response relation has yet to be determined.
2.2.6 Physical activity and the metabolic syndrome

The metabolic syndrome (MetS) is a clustering of risk factors for cardiovascular disease and type 2 diabetes including abdominal obesity, dyslipidemia, high blood pressure, and elevated blood glucose. The International Diabetes Federation indicates that adults with the MetS are three to five times more likely to develop cardiovascular disease (myocardial infarction or stroke) and type 2 diabetes in comparison to adults without the MetS. Cardiovascular disease and type 2 diabetes are typically considered to be ‘adult onset’ diseases, but the origins of these chronic diseases are known to start in childhood.

Although few studies have examined the relationship between physical activity and MetS in youth, experimental studies have shown improvements in many elements of MetS (triglycerides, insulin, obesity) with increased physical activity in both normal-weight and overweight/obese youth. Odds for having the MetS increase with decreasing levels of physical activity such that inactive youth are three times more likely to have the MetS than their active counterparts. The amount and intensity of physical activity needed for the prevention of MetS is unknown, but greater doses of physical activity seem to be associated with higher levels of metabolic health.
2.3 Physical activity levels of Canadian children and youth

This section highlights the findings from recent research that has examined the physical activity levels in Canadian children and youth. Unfortunately, there are limited standardized and representative surveillance data on physical activity in Canadian children and youth and the surveillance data that is available is often not congruent with Canadian physical activity guidelines. Although Canadian guidelines recommend 90 min/d of MVPA, most of the previous research (even within Canada) has based their results on international guidelines of 60 min/d of MVPA. Furthermore, physical activity surveillance data is typically based on measures from self-reported or parental reported questionnaires, the limitations of which are discussed in detail later on in this literature review.

For the third year in a row, Canada’s 2009 Report Card on physical activity and health in children and youth assigned a falling grade of “F” for the physical activity indicator. The Report Card highlights findings from 2008/2009 CANPLAY study (Canadian Physical Activity Levels Among Youth), which indicate that 87% of children and youth are not meeting Canadian physical activity guidelines. The results from the CANPLAY study provide the first objective measures of physical activity on a representative sample of Canadian children and youth. Pedometers were used to assess activity levels on approximately 10,000 school-aged children and youth from across the country. On a positive note, results from the 2008/2009 CANPLAY show that youth are
slightly more active (by 5-6 min/day) than in 2006/2007. However, further surveillance is needed to see if this modest increase in activity will continue to increase over time.

Prior to 2006, all of the surveillance data on physical activity levels in Canadian children and youth was based on subjective measures of physical activity (e.g., self-reported questionnaire). These results were not as dismal as those reported for the CANPLAY study. For example, findings from the 2001/2002 Canadian Community Health Survey indicated that 41.1% of 12-19 years old Canadian youth were active for at least 60 minutes per day. This is consistent with self-report physical activity data taken from the Health and Behaviour in School-Aged Youth survey. Within this survey, Canadian youth in grade 6-10 were considered physically active if they participated in at least 60 minutes of physical activity on 5-7 days per week. In 2002, only 49% of youth were considered active. Results from the 2006 cycle of this survey were slightly more encouraging as 54% of youth were considered active.

2.3.1 Physical activity guidelines for children and youth

In 1988 the American College of Sports Medicine published an opinion statement which suggested that children and youth should obtain 20-30 minutes of vigorous exercise every day. This report aimed to provide direction regarding physical activity in children and youth but stated that the amount of physical activity needed to optimal
functional capacity could not be precisely defined. Since 1988 many countries and organizations have produced evidence-based recommendations on the amount of physical activity children and youth should obtain to maintain good health, as revised elsewhere.\textsuperscript{24} With few exceptions, the general consensus has been that school-aged children and youth should accumulate 60 minutes of moderate-to-vigorous physical activity every day.

The most rigorous and evidence-based approach for developing pediatric physical activity guidelines was part of the Physical Activity Guidelines for Americans project conducted by the U.S. Centers for Disease Control and Prevention (CDC).\textsuperscript{2} The CDC worked with an advisory committee, made up of research experts from across the country, to systematically evaluate and organize previous research focused on the health outcomes of physical activity in school-aged children and youth. The evaluation process took nearly two years to complete. The authors were given strict instructions to maintain homogeneity throughout the report and were required to include information that pertained to: the type of evidence (e.g., observational studies, randomized control trials etc); the strength of the evidence; characteristics of physical activity (e.g., intensity, duration, etc); any evidence for dose-response; and any evidence that sedentary behaviours increase an individual’s risk. The Physical Activity Guidelines Advisory Committee Report concluded that children and youth should engage in 60 minutes of moderate-to-vigorous physical activity on all days of the week. The activity
does not need to be continuous but should include components of aerobic activities, muscle-strengthening activities, and bone-strengthening activities. There was not enough evidence in the current literature for the report to make any conclusions about dose-response relations between physical activity and individual health outcomes in children and youth. Another recently published systematic review by Strong et al., made similar conclusions and also suggested that school-aged youth should accumulate 60 minutes of moderate-to-vigorous physical activity per day.

In 2002, Health Canada and the Canadian Society for Exercise Physiology introduced the first set of physical activity guidelines for Canadian children and youth. Basic recommendations from these guidelines state that independent of current activity status, children and youth should gradually increase their time spent being active by 90 minutes per day. This increase in physical activity should include at least 60 minutes of moderate intensity activity (e.g., brisk walking, bicycling) and 30 minutes of vigorous physical activity (e.g., running, playing soccer). Activities should be varied and include movements that enhance endurance, flexibility, and strength. Canada’s current physical activity guidelines are unique to other guidelines in that they do not give an absolute recommendation for the amount of time children and youth should engage in physical activity. Instead, Canadian guidelines state that regardless of current activity patterns children and youth should gradually increase their time spent being active by at least 90 minutes per day. A recently published narrative review of
literature on the Canadian physical activity guidelines indicated that there is limited evidence to suggest that children and youth need to obtain such a large volume of MVPA before substantive health benefits occur.\(^{24}\)

### 2.4 Dose-response relationship between physical activity and health in children and youth

Currently, there is strong evidence to suggest that children and youth who participate in 60 min/day of MVPA will obtain numerous health benefits.\(^{2,3}\) However, there is limited research examining the dose-response relation between physical activity and selected health outcomes in this age group.\(^{2,3}\) Dose-response relationships are useful to determine the thresholds for minimal and optimal health benefits; dose being the amount of physical activity that the individual engages in and response being its associated effect on a specified health outcome.\(^{27}\)

The dose-response relation between physical activity and a wide range of health outcomes has been well studied in the adult population.\(^{2}\) Studies in adult populations have suggested that the relationship between moderate-to-vigorous intensity physical activity and many health/disease outcomes is curvilinear such that there are large health benefits with increases in physical activity at the lower end of the physical activity spectrum, and only modest additional improvements in health with further increases physical activity at the upper end of the physical activity spectrum (line A in
As a reflection of this dose-response relationship, physical activity guidelines for adults are quite modest, with a recommendation of 30-60 minutes of MVPA on most days of the week.28

**Figure 1.2** Possible dose-response patterns to explain the relation between physical activity and possible health outcome

There has been limited research examining dose-response relationships between physical activity and health in children and youth, and the limited number of dose-response studies conducted have been methodologically flawed, as acknowledged in several recent systematic reviews and consensus reports.2,3,24 I have chosen to illustrate the dose-response issues on physical activity and health in the pediatric population using plasma lipid/lipoproteins as an example health outcome. This outcome was chosen because it has been well studied in the pediatric exercise sciences8,11,15,29-33 and because of its importance to cardiovascular health.8,11,34
The influence of physical activity on blood lipids and lipoproteins has been extensively studied in both adults and children.\textsuperscript{11,12,31,35-43} It is generally recognized that MVPA has favourable effects on HDL-cholesterol and triglycerides. The influence of physical activity on LDL-cholesterol, particularly with children, is unclear.\textsuperscript{2} Although the relation between physical activity and lipids has been extensively studied, to my knowledge only two studies have attempted to explore the dose-response nature of these relations within children and youth.

An intervention study by Tolfrey and colleagues\textsuperscript{33} examined the effect of two different doses of physical activity on lipids and lipoproteins using an intervention design. This study, conducted on a small sample (n=36), compared changes in lipid/lipoprotein values between low (~60 min/week) and moderate (~78 min/week) exercise intervention groups over a 12 week period. Significant changes in lipid/lipoprotein values were not found in either intervention group. It is not surprising that the results of this study did not reach significance given the small (~18 min/week) difference between low and moderate exercise groups. Furthermore, even the dose of physical activity prescribed for the highest group would be considered insufficient in relation to existing national and international physical activity guidelines.

The second study was a cross-sectional study of 2358 young Finns aged 9-24 years.\textsuperscript{30} Participants were classified as inactive, moderately active, or physically active based on their responses to a physical activity questionnaire. Plasma triglycerides and
HDL-cholesterol were significantly more favourable in the physically active group. Although not significant, plasma LDL-cholesterol tended to be lower in those with increased levels of physical activity. There were several limitations to this study that make it difficult to discern the dose-response relation. The first limitation was that participants were grouped into tertiles of activity; the limited number of exposure categories considered makes it difficult to discern the nature of the dose response relation (e.g., linear, curvilinear, etc.). The second limitation of this research is that physical activity was measured with self-report questionnaires. The limitations of subjective measures of physical activity (such as self-report physical activity questionnaires) will be discussed in greater detail later on; however, it is important to recognize here that there is a general overestimation of actual levels of physical activity with self-reported measures.44

This review has focused on the available evidence surrounding the dose-response relation between lipids and lipoproteins and physical activity in children and youth. Currently, there is limited research examining dose-response relations between physical activity and other health outcomes in the pediatric population.2 As with the studies for lipids and lipoproteins discussed in the preceding few paragraphs, most of these studies had severe methodological flaws. Most notably, previous dose-response studies in children and youth have relied on self-report measures of physical activity.
The next section of this review of literature will focus on the discrepancies between self-reported and objectively measured physical activity in the pediatric population.

2.5 Discrepancies between subjective and objective measures of physical activity

Subjective measures of physical activity, such as those obtained by self-reported questionnaire, have been most often used in population based research due to their low cost, ease of use, and overall feasibility. However, there is concern about the validity of self-report measures, especially in the pediatric population. Children and youth tend to over-estimate their time spent being active either through a misunderstanding of what is considered moderate intensity activity or by a social desirability bias. In recent years, researchers have started to employ objective physical activity measures, such as those obtained by accelerometer. Therefore, to put the emerging literature into historical context, it is important to appreciate the differences between subjective and objective measures of physical activity.

A newly published systematic review by Adamo and colleagues looked at 83 articles comparing self-report and objective measures of physical activity in children and youth. Of the 83 published studies included in this review, 72% reported that children and youth significantly over-reported their physical activity. A total of 11 studies within the systematic review compared self-report and accelerometer measurements; these studies found an average difference of 147% between measures.
A careful examination of the studies included within this systematic review highlights a few key limitations in the existing literature and raises some additional questions. First, the previous studies were based on relatively small and homogeneous samples. Thus, it is unclear as to whether the differences between self-reported and objective measures of MVPA vary according age, sex, and ethnicity. Second, although it is clear that a discrepancy exists between self-reported and objective measures, it is unknown as to whether the difference varies across the physical activity scale. In other words, do both inactive and physically active youth over-report their level of physical activity, or is this issue limited to inactive youth?

After completing my own review of literature and cross-referencing this to the systematic review by Adamo and colleagues, I summarized the results from the 21 published studies that best reflect the population group (youth aged 12+) and measurement techniques (accelerometer measures of activity) that I will employ in my thesis (Table 1). The pattern of results and limitations of these 21 studies is comparable to those of the larger systematic review.
<table>
<thead>
<tr>
<th>Study and year</th>
<th>Self-reported measurement</th>
<th>Study population</th>
<th>Key results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lachat et al. (2008)</td>
<td>International Physical Activity Questionnaire (IPAQ) and Physical Activity Questionnaire for Adolescents (PAQA)</td>
<td>277 Not reported age=16 grade 11</td>
<td>Results from IPAQ/PAQA gave longer durations for MVPA than accel 46% of subjects active for 30min/d by accel vs. 78% by IPAQ and 94% by PAQA</td>
</tr>
<tr>
<td>Stanley et al. (2007)</td>
<td>3-Day Physical Activity Recall</td>
<td>20 0 20 mean=12.25 range 12-14</td>
<td>Significant correlation between accel and self-reported measures (r=0.63)</td>
</tr>
<tr>
<td>Ekelund et al. (2006)</td>
<td>Swedish Adolescent Physical Activity Questionnaire</td>
<td>50 19 31 mean=16.8</td>
<td>Significant correlation between accel and questionnaire (r=0.44) No significant difference in reporting by sex or age</td>
</tr>
<tr>
<td>Wong et al. (2006)</td>
<td>School Health Action, Planning, and Evaluation System Questionnaire</td>
<td>53 28 25 grade 6-8, 10, 12</td>
<td>Significant correlation between accel and questionnaire for MVPA (r=0.44)</td>
</tr>
<tr>
<td>Anderson et al. (2005)</td>
<td>Previous Day Physical Activity Recall and Self Administered Physical Activity Recall</td>
<td>80 37 43 mean boys=13.4 mean girls=13.3</td>
<td>Self-reported measures over-reported MVPA and vigorous activity Moderate correlations between accel and self-reported MVPA (r=0.42) and vigorous activity (r=0.22)</td>
</tr>
<tr>
<td>Study</td>
<td>Methodology</td>
<td>n</td>
<td>Mean</td>
</tr>
<tr>
<td>------------------------------</td>
<td>----------------------------------------------------------------------------</td>
<td>----</td>
<td>--------</td>
</tr>
<tr>
<td>Argiropoulou et al. (2004)</td>
<td>3-Day Physical Activity Recall, 4-By-1-Day Recall Questionnaire, and Physical Activity and Lifestyle Questionnaire</td>
<td>40</td>
<td>23</td>
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<tr>
<td>Cradock et al. (2004)</td>
<td>Interviewer prompted 24-h physical activity recall</td>
<td>43</td>
<td>26</td>
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<tr>
<td>McMurray et al. (2004)</td>
<td>3-Day Physical Activity Recall and Self Administered Physical Activity Recall</td>
<td>320</td>
<td>114</td>
</tr>
<tr>
<td>Pate et al. (2003)</td>
<td>3-Day Physical Activity Recall</td>
<td>70</td>
<td>0</td>
</tr>
<tr>
<td>Tudor-Locke et al. (2003)</td>
<td>24-hour Physical Activity Recall</td>
<td>1546</td>
<td>715</td>
</tr>
<tr>
<td>De Ridder et al. (2002)</td>
<td>Weight Bearing Activity Questionnaire for Kids</td>
<td>72</td>
<td>35</td>
</tr>
<tr>
<td>Study</td>
<td>Measure</td>
<td>Sample Size</td>
<td>Boys</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>----------------------------------------</td>
<td>-------------</td>
<td>------</td>
</tr>
<tr>
<td>Mota et al. (2002)</td>
<td>Weekly Activity Checklist</td>
<td>109</td>
<td>42</td>
</tr>
<tr>
<td>Rodriguez et al. (2002)</td>
<td>Activity Diary</td>
<td>20</td>
<td>13</td>
</tr>
<tr>
<td>Crocker et al. (2001)</td>
<td>Physical Activity Questionnaire for Older Children (PAQ-C) Physical Activity Recall (PAR)</td>
<td>61</td>
<td>34</td>
</tr>
<tr>
<td>Allor et al. (2000)</td>
<td>Physical Activity Recall</td>
<td>46</td>
<td>0</td>
</tr>
<tr>
<td>Trost et al. (1999)</td>
<td>Self-report questionnaire</td>
<td>198</td>
<td>95</td>
</tr>
<tr>
<td>Study</td>
<td>Methodology</td>
<td>N</td>
<td>Mean</td>
</tr>
<tr>
<td>------------------------------</td>
<td>----------------------------------------------------------------------------</td>
<td>-----</td>
<td>------</td>
</tr>
<tr>
<td>Kowalski et al. (1997)</td>
<td>Physical Activity Questionnaire for Adolescents (PAQ-A), Physical Activity Recall (PAR), Activity Rating, and Leisure Time Exercise Questionnaire</td>
<td>85</td>
<td>41</td>
</tr>
<tr>
<td>Kowalski et al. (1997)</td>
<td>Physical Activity Questionnaire for Older Children</td>
<td>97</td>
<td>41</td>
</tr>
<tr>
<td>Weston et al. (1997)</td>
<td>Previous Day Physical Activity Recall</td>
<td>112</td>
<td>56</td>
</tr>
<tr>
<td>Epstein et al. (1996)</td>
<td>Self-report activity diaries</td>
<td>59</td>
<td>20</td>
</tr>
<tr>
<td>Janz et al. (1995)</td>
<td>3-Day sweat recall, 3-Day aerobic recall, Physical Activity Rating</td>
<td>30</td>
<td>15</td>
</tr>
</tbody>
</table>
2.6 Summary and conclusions

Physical activity is associated with numerous health benefits in children and youth.\textsuperscript{2,3} Unfortunately, most Canadian children and youth are not active enough to meet either Canadian or international physical activity guidelines.\textsuperscript{20,21} Current physical activity guidelines for children and youth are based on limited and poor evidence on the dose-response relation between physical activity and health. Furthermore, previous research examining the dose-response relation between physical activity and health has typically relied on subjective measures (e.g., self-report questionnaires) of physical activity. Population based researchers are now able to employ objective measures of physical activity (e.g., accelerometers) to accurately determine the volume of physical activity, and to accurately characterize the dose-response relation between physical activity and health outcomes. The information from these types of studies will be useful for developing more informed physical activity guidelines on the minimal and optimal amount of physical activity required for good health in the pediatric population.

2.7 Thesis objectives

The objectives of this thesis were to:

1. Determine the dose-response relationship between moderate-to-vigorous intensity physical activity and plasma lipids/lipoproteins in youth (12-19 years of age). The lipids/lipoproteins examined include those that are measured in the clinical setting: LDL-cholesterol, HDL-cholesterol, and triglycerides.
2. Examine the relation between self-reported and accelerometer measured moderate-to-vigorous intensity physical activity in youth. Specifically, the objectives were to: 1) quantify the magnitude of the difference between self-reported and accelerometer measured moderate-to-vigorous intensity physical activity in youth, 2) determine whether the difference between self-report and accelerometer measures varies across the moderate-to-vigorous intensity physical activity spectrum, and 3) determine whether this difference is influenced by demographic characteristics (sex, age, race/ethnicity).
2.8 References


CHAPTER 3

DOSE-RESPONSE RELATION BETWEEN PHYSICAL ACTIVITY AND

DYSLIPIDEMIA IN YOUTH

This manuscript has been submitted to the American Heart Journal and follows the formatting requirements of the journal

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Short title: Physical activity and dyslipidemia in youth

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3.1 Abstract

Background: The minimal and optimal amount of physical activity associated with cardiovascular health benefits in young people is unknown. The purpose of this study was to determine the dose-response relationship between moderate-to-vigorous physical activity (MVPA) with high-risk LDL-cholesterol, HDL-cholesterol, and triglyceride values in youth.

Methods: The study sample consisted of 1235 youth (12-19 years) from the 2003-2005 U.S. National Health and Nutrition Examination Survey. Objective measures of MVPA were obtained over 7 days with Actigraph accelerometers. LDL-cholesterol, HDL-cholesterol, and triglycerides were measured from a fasting blood sample. High-risk plasma lipid values were determined using age- and gender-specific thresholds. Thirty six logistic regression models, each containing a different set of fractional polynomials for MVPA, were used to determine the dose-response relationships between MVPA with high-risk lipid levels.

Results: Risks for high-risk HDL-cholesterol and triglyceride values decreased in a curvilinear manner with increasing min/d of MVPA. At 15 min/d, 30 min/d, and 60 min/d of MVPA, the odds ratio (95% confidence interval) for low HDL-cholesterol were 0.29 (0.13-0.67), 0.24 (0.10-0.64), and 0.21 (0.07-0.61) respectively, compared to 1 min/d of MVPA. The corresponding odds ratios for high triglycerides were 0.40 (0.18-0.76), 0.22
(0.06-0.66), and 0.10 (0.01-0.51). There was no discernable dose-response relation between MVPA and LDL-cholesterol.

**Conclusion:** Modest amounts of MVPA were associated with a large reduction in the likelihood of having high-risk HDL-cholesterol and triglyceride values in this representative sample of adolescents. The greatest reduction in risk occurred within the first 30 min/d of MVPA.
3.2 Introduction

Although the clinical manifestations of cardiovascular disease do not typically occur until old age, the process of atherosclerosis begins in childhood.\textsuperscript{1} Children and youth with elevated risk factors for cardiovascular disease, such as high LDL-cholesterol and low HDL-cholesterol, are at increased risk of having these risk factors as adults.\textsuperscript{2-4} In addition, plasma lipid levels during childhood and adolescence predict the degree of atherosclerosis in early adulthood.\textsuperscript{5} It is therefore important to maintain a healthy plasma lipid profile even at a young age.

Physical activity is an important component of the therapeutic lifestyle recommendations for preventing and treating abnormal plasma lipids levels (dyslipidemia) in children and youth.\textsuperscript{27-29} Recent public health guidelines of the American Heart Association\textsuperscript{6} and Centers for Disease Control and Prevention (CDC)\textsuperscript{7} indicate that children and youth should engage in 60 minutes of moderate-to-vigorous physical activity (MVPA) on a daily basis to maintain good cardiovascular health. The evidence-based advisory report from which the CDC guidelines were developed note that children and youth who engage in large amounts of MVPA have a more favorable cardiovascular risk factor profile than sedentary youth.\textsuperscript{7} However, the nature of the dose-response relationship between MVPA and plasma lipid levels in youth has yet to be determined, and the minimal and optimal amount of physical activity required for cardiometabolic
health in youth is unclear. Therefore, the purpose of this study was to determine the dose-response relationship between MVPA and dyslipidemia in youth.

3.3 Methods

Data Source

The study sample included adolescents (12-19 years) from the 2003/2004 and 2005/2006 cycles of the U.S. National Health and Nutrition Examination Survey (NHANES) who completed both the home interview and mobile examination center portions of the survey. Of the 2202 eligible participants, 738 did not have acceptable physical activity data (explained below) and an additional 229 did not have fasting (≥9 hours) blood measures. The current study was therefore limited to 1235 participants (659 boys, 576 girls). There was no statistical differences in sex and race between participants who were included in the analysis vs. those who were excluded because of missing data (P>0.1).

NHANES is a representative cross-sectional survey of the United States. Participants were identified using a complex stratified, multistage probability sampling technique. More information pertaining to the NHANES survey methodology can be found in Appendix C. Informed consent was obtained from all participants and their parents or guardians if under the age of consent (Appendix D). The study protocol was approved by the National Center for Health Statistics. The secondary analysis presented
here was approved by the Queen’s University Health Sciences Research Ethics Board (Appendix E).

Physical Activity

Physical activity was measured objectively using Actigraph AM-7164 accelerometers (Actigraph, Ft. Walton Beach, FL, USA). More in depth details and information on and the measurement of physical activity with accelerometers can be found in Appendix F. Briefly, Actigraph AM-7164 accelerometers are uniaxial monitors used to measure vertical accelerations between 0.05 and 2.00 G in magnitude and at a frequency between 0.25 and 2.50 Hz. These parameters reduce spurious data caused by vibrations from outside sources and restrict monitoring to normal human movement. The filtered movement is stored as an activity count for a user-specified ‘epoch’ interval. Epochs were set to one-minute to determine the participant’s minute-by-minute physical activity intensity.

Accelerometers were given out at the completion of the mobile exam center exam and were programmed to begin recording at 12:01 a.m. the following day. Monitors were worn for 7 consecutive days and attached with an elastic belt to the right hip and participants were given a information package for proper use of the accelerometers (Appendix G). Thus, for each participant there were 10,080 epoch values (one for each minute of the week), with each of these values corresponding to their intensity of movement during that minute. Participants were asked to wear their accelerometer
during all waking hours, except when it would get wet (e.g., water sports, showering/bathing).

The 10,080 epoch values were downloaded from the accelerometers by the CDC and checked for biologically implausible data. Additional data reduction was completed by the study authors before analysis. Specifically, participants were only included in the analysis if they had complete monitoring data for at least 4 days, including at least one weekend day. Days are considered complete if there is at least 10 hours of monitoring time. Periods of 20 minutes or more of zero counts were assumed to indicate non-wear time and did not count towards the total wear time. Within adolescents, four days of physical activity monitoring using accelerometers has a test-re-test reliability correlation coefficient of 0.70. An epoch threshold of ≥3000 counts per minute was used to denote minutes of MVPA. This threshold is based on previous validation studies conducted in a similar age group and corresponds to a MET equivalent of 3.0 (e.g., brisk walking). For each complete day of monitoring, data was filtered to determine the number of minutes spent engaged in: 1) bouts of MVPA (≥5 minutes), and 2) sporadic MVPA (<5 minutes). To calculate a bout of MVPA, we determined the number of minutes in which participants spent at least 80% of the time above the threshold for MVPA (e.g., for a 10 minute bout, 8 minutes would have to be above 3000 counts/minute and this would count as 10 minutes). Furthermore, bouts had to be at least 5 minutes in duration. The 80%
threshold allowed us to account for the occasional rest period observed during bouts of physical activity (e.g., the short break between a goal in soccer and the re-start of the game). Sporadic physical activity was calculated as those minutes outside of bouts in which participants achieved the 3000 counts/minute threshold. Total MVPA for each day was then calculated as the sum of bouts and sporadic activity. Total minutes of MVPA were then averaged over the 4-7 day monitoring period to create a final variable for each participant that reflected their average MVPA in minutes per day.

Plasma Lipids and Lipoproteins

The study outcomes consisted of the plasma lipids that can be readily measured in the clinical setting and which are the primary and secondary targets for lipid management: LDL-cholesterol, HDL-cholesterol, and triglycerides. General information regarding metabolism of lipids/lipoproteins can be found in Appendix A. Blood samples were obtained after an overnight fast during the mobile exam center visit. All blood specimens were shipped, stored, and processed at the Johns Hopkins University Lipoprotein Analytical Laboratory. A brief description of blood analysis procedures is described below. Detailed methodology can be obtained elsewhere.\textsuperscript{31}

Total cholesterol was measured enzymatically in serum in a series of coupled reactions using cholesteryl ester hydrolase, cholesterol oxidase and peroxidase. Triglycerides were measured enzymatically through a series of coupled reactions where triglycerides were hydrolyzed to produce glycerol which is then oxidized once more to
produce H$_2$O$_2$. Absorbance was measured (set at 500nm) to determine levels of serum triglycerides. HDL-cholesterol was measured using the Roche/Boehringer-Mannheim Diagnostics direct HDL method and analyzed using the direct HDL-cholesterol immunoassay method. The bias for the HDL-cholesterol values in the 2003-2004 NHANES cycle were acceptable (<4%) and did not need to be corrected; however, values from the 2005-2006 cycle were biased (>4%) when compared to control samples (Soloman Park Research Laboratories, Kirkland, WA). These values were corrected using the following formula: corrected HDL-cholesterol = [(Soloman Park assigned HDL value) x (participant’s HDL)] / [(quality control HDL associated with participant’s sample)]. LDL-cholesterol was estimated from the Friedewald equation as: LDL-cholesterol = [(total cholesterol) - (HDL-cholesterol)] - [(triglycerides)/5]

Previous intervention research has suggested physical activity has a minimal effect on plasma lipids in individual whose values are within the normal healthy range. Therefore, the analyses in this paper focused on predicting individuals with ‘high-risk’ lipid values. High-risk LDL-cholesterol, HDL-cholesterol, and triglyceride values were determined using the age- and gender-specific values that were developed by Joliffie and Janssen (Appendix B). These thresholds were developed using growth curve modeling and correspond at entry into adulthood (20.0 years) to the adult cut-points established by the U.S. National Cholesterol Education Program (LDL-cholesterol ≥4.14 mmol/L, HDL-cholesterol ≤1.04 mmol/L, triglycerides ≥2.26 mmol/L).
Covariates

Demographic information on ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, and other), age (to the nearest month), sex, and socio-economic status were used as covariates. The poverty-to-income ratio was used as a measure of socio-economic status. This threshold varies by family size and income and is updated yearly by the U.S. Census Bureau to account for inflation.\textsuperscript{17}

Better overall dietary habits are associated with increased levels of physical activity\textsuperscript{18} and favorable plasma lipid levels. Total caloric content and the intake of sugar, dietary fiber, and saturated fats were used as covariates. Dietary values were obtained by averaging the results from two separate 24-hour food recall questionnaires (one in-person, one on the telephone). The dietary variables were included in the analyses as continuous measures. Obesity and adiposity were not included as covariates since they were assumed to be an intermediate factor between the exposure (level of MVPA) and outcome (risk of dyslipidemia).

Statistical Analysis

Statistical analysis was performed using SAS 9.1 (SAS Institute, Cary, NC, USA) and took into account the sample weights and clustered nature of the NHANES survey. Because the MVPA and triglyceride values were positively skewed, the descriptive data has been presented as medians and interquartile ranges. Unpaired t-tests were used to
determine age and gender differences in MVPA. The MVPA values were log transformed for the t-test analyses.

Logistic regression was used to predict the odds of having ‘high-risk’ LDL-cholesterol, HDL-cholesterol, and triglyceride values according the level of MVPA. Thirty-six different logistic regression models were run for each of the plasma lipids. Each of these models contained a different combination of fractional polynomial models for the continuous MVPA measure. The model with the lowest Akaike Information Criterion (AIC) was considered to be the model with the best fit, and the parameters from this model were used to plot the dose-response curve between MVPA and ‘high-risk’ plasma lipid/lipoprotein values. This analysis strategy has been described by Bagnardi and colleagues and is concerned with finding the best model fit rather than simply determining the significance of the relationship between the exposure (MVPA) and outcome (plasma lipids). Bootstrapping was used to estimate the 95% confidence intervals for the logistic regression analyses.

3.4 Results

Basic descriptive information on the study sample is shown in Table 3.1. The median MVPA value was 15.7 min/d with an interquartile range of 7.0-30.7 min/d. Boys engaged in significantly more MVPA than girls (median of 29.4 vs. 12.7 min/d, P<0.0001). Only 4.1% of youth met physical activity guidelines of 60 min/d, and 34.8% of boys and
71.1% of girls accumulated less than 15 min/d of MVPA. Average dietary values for total caloric intake, sugar, fiber, and saturated fats are presented in Table 3.2. Boys had significantly higher values for all dietary variables (P<0.0001). Using the U.S. Census Bureau definition, 68.2% of youth were considered to be above the poverty threshold.¹⁷
Table 3.1 Descriptive characteristics of participants

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total (n=1235)</th>
<th>Males (n=659)</th>
<th>Females (n=576)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ethnicity, %</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Hispanic white</td>
<td>24.4</td>
<td>24.8</td>
<td>23.9</td>
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<tr>
<td>Hispanic</td>
<td>36.4</td>
<td>34.3</td>
<td>38.8</td>
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<tr>
<td>Non-Hispanic black</td>
<td>35.3</td>
<td>37.5</td>
<td>32.8</td>
</tr>
<tr>
<td>Other</td>
<td>4.0</td>
<td>3.5</td>
<td>4.6</td>
</tr>
<tr>
<td><strong>Age, %</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12-13 yr</td>
<td>28.3</td>
<td>29.3</td>
<td>27.1</td>
</tr>
<tr>
<td>14-16 yr</td>
<td>36.9</td>
<td>36.3</td>
<td>37.7</td>
</tr>
<tr>
<td>17-19 yr</td>
<td>35.0</td>
<td>34.5</td>
<td>35.2</td>
</tr>
<tr>
<td><strong>MVPA, %</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-14 min/d</td>
<td>51.8</td>
<td>34.8</td>
<td>71.1</td>
</tr>
<tr>
<td>15-29 min/d</td>
<td>25.9</td>
<td>30.5</td>
<td>20.7</td>
</tr>
<tr>
<td>30-59 min/d</td>
<td>17.9</td>
<td>27.0</td>
<td>7.6</td>
</tr>
<tr>
<td>≥60 min/d</td>
<td>4.4</td>
<td>7.8</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Table 3.2 Descriptive dietary characteristics of participants

<table>
<thead>
<tr>
<th></th>
<th>Total mean (SD)</th>
<th>Boys mean (SD)</th>
<th>Girls mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total caloric intake, total kcal/d</strong></td>
<td>2187.7 (839.7)</td>
<td>2423.0 (899.1)</td>
<td>1934.0 (686.0)</td>
</tr>
<tr>
<td><strong>Sugar, grams/d</strong></td>
<td>141.5 (71.7)</td>
<td>157.9 (78.3)</td>
<td>123.7 (59.0)</td>
</tr>
<tr>
<td><strong>Dietary Fiber, grams/d</strong></td>
<td>14.11 (7.4)</td>
<td>15.2 (7.6)</td>
<td>12.9 (6.9)</td>
</tr>
<tr>
<td><strong>Saturated Fat, grams/d</strong></td>
<td>27.6 (12.8)</td>
<td>30.7 (13.7)</td>
<td>24.3 (10.9)</td>
</tr>
</tbody>
</table>
Plasma lipid values are presented in Table 3.4 (Page 69). A small proportion of the participants (4.4% of boys, 5.4% of girls) had high-risk triglyceride values and even fewer (2.0% of boys, 3.8% of girls) had high-risk LDL-cholesterol values. A higher proportion of participants had high-risk HDL-cholesterol values (18.2% of boys, 12.2% of girls).

The adjusted odds ratios for the relation between the covariates and high-risk LDL-cholesterol, HDL-cholesterol, and triglyceride values are shown in Table 3.3 (Page 70). Sex was significantly related to HDL-cholesterol. Race (Hispanic) was a significant predictor for high LDL-cholesterol. Race (non-Hispanic black) was also a significant predictor of high triglyceride values.

Relations between MVPA and high-risk plasma lipid values were modeled for MVPA values ranging from 1 min/d to the 98th percentile (Figure 3.1 on page 71). There was no discernable dose-response relation between MVPA and high-risk LDL-cholesterol as the 95% confidence intervals crossed one throughout the MVPA range (Figure 3.1, Panel A). The likelihood for having low HDL-cholesterol values decreased in a curvilinear manner with increasing minutes of MVPA (Figure 3.1, Panel B). At 15 min/d, 30 min/d and 60 min/d of MVPA the odds ratios (95% confidence interval) for high-risk HDL-cholesterol were 0.29 (0.13-0.67), 0.24 (0.10-0.64) and 0.21 (0.07-0.61), respectively, compared to 1 min/d of MVPA. The likelihood of having high-risk triglyceride values also decreased in a curvilinear manner with increasing minutes of MVPA (Figure 3.1, Panel C). At 15 min/d,
Table 3.3 Descriptive information for LDL-cholesterol, HDL-cholesterol, and triglycerides measures

<table>
<thead>
<tr>
<th>Lipid variable</th>
<th>Total (n=1235)</th>
<th>Males (n=659)</th>
<th>Females (n=576)</th>
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<tbody>
<tr>
<td></td>
<td>Median (interquartile range)</td>
<td>% with high-risk value</td>
<td>Median (interquartile range)</td>
</tr>
<tr>
<td>LDL-cholesterol*</td>
<td>2.25 (1.84-2.71)</td>
<td>2.8</td>
<td>2.17 (1.81-2.66)</td>
</tr>
<tr>
<td>HDL-cholesterol*</td>
<td>1.32 (1.16-1.60)</td>
<td>15.4</td>
<td>1.27 (1.14-1.55)</td>
</tr>
<tr>
<td>Triglycerides*</td>
<td>0.86 (0.59-1.12)</td>
<td>4.8</td>
<td>0.82 (0.58-1.12)</td>
</tr>
</tbody>
</table>

* Median LDL-cholesterol, HDL-cholesterol, and triglyceride values are presented in mmol/L. To covert LDL-cholesterol and HDL-cholesterol values from mmol/L to mg/dL multiply by a factor of 38.67. To convert triglyceride values in mmol/L to mg/dL multiply by a factor of 88.5.
30 min/d, and 60 min/d of MVPA the odds ratios for high-risk triglycerides were 0.40 (0.18-0.76), 0.22 (0.06-0.66) and 0.10 (0.01-0.51), respectively, compared to 1 min/d of MVPA.

**Table 3.4** Adjusted odds ratios for the relation between covariates and unfavourable lipid/lipoprotein levels in relation to physical activity

<table>
<thead>
<tr>
<th></th>
<th>LDL-cholesterol</th>
<th>HDL-cholesterol</th>
<th>triglycerides</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographic characteristics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PIR</td>
<td>1.99 (0.62-6.39)</td>
<td>1.48 (0.87-2.54)</td>
<td>1.64 (0.61-4.40)</td>
</tr>
<tr>
<td>Sex</td>
<td>1.13 (0.36-4.02)</td>
<td>0.26 (0.15-0.46) *</td>
<td>0.41 (0.15-1.08)</td>
</tr>
<tr>
<td>Age</td>
<td>0.92 (0.74-1.17)</td>
<td>1.05 (0.94-1.17)</td>
<td>0.88 (0.71-1.09)</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>0.24 (0.08-0.78) *</td>
<td>0.76 (0.46-1.29)</td>
<td>0.75 (0.34-1.68)</td>
</tr>
<tr>
<td>Non-Hispanic black</td>
<td>0.55 (0.17-1.77)</td>
<td>0.61 (0.38-1.01)</td>
<td>0.29 (0.11-0.76) *</td>
</tr>
<tr>
<td><strong>Dietary variables</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total kcal</td>
<td>1.00 (1.00-1.00)</td>
<td>1.00 (1.00-1.00)</td>
<td>1.00 (1.00-1.00)</td>
</tr>
<tr>
<td>Sugar</td>
<td>1.00 (0.99-1.01)</td>
<td>1.00 (1.00-1.01)</td>
<td>0.99 (0.98-1.00)</td>
</tr>
<tr>
<td>Fiber</td>
<td>1.01 (0.95-1.10)</td>
<td>1.01 (0.96-1.06)</td>
<td>0.98 (0.90-1.07)</td>
</tr>
<tr>
<td>Saturated fat</td>
<td>1.01 (0.33-1.37)</td>
<td>0.98 (0.94-1.02)</td>
<td>0.94 (0.86-1.02)</td>
</tr>
</tbody>
</table>

*significant effect for predicting odds ratio for low HDL-cholesterol and high triglyceride values.
**Figure 3.1** Odds ratio for high-risk LDL-cholesterol values (Panel A), high-risk HDL cholesterol values (Panel B), and high risk triglyceride values (Panel C) according to average min/day of moderate-to-vigorous physical activity (MVPA). 1 min/day represents the referent value (odds ratio = 1.0) for MVPA. Solid lines represent the predicted odds ratios and dotted lines represent the 95% confidence intervals.
3.5 Discussion

The objective of this study was to examine the dose-response relation between MVPA and high-risk plasma lipid values in youth. A curvilinear dose-response relationship was observed with HDL-cholesterol and triglycerides such that the greatest effect of MVPA was observed within the first 30 min/d. There was no clear relation between MVPA and high-risk LDL-cholesterol.

The observation of a decreased odds high-risk HDL-cholesterol and triglycerides with increasing MVPA is consistent with previous observational studies in youth. Intervention studies have also demonstrated improvements in HDL-cholesterol and triglycerides with increases in exercise in youth. Research examining the relation between physical activity and LDL-cholesterol in both adults and youth is contradictory. Within the adult population, endurance athletes have LDL-cholesterol levels that are only 8-10% lower than their sedentary counterparts. Conversely, HDL-cholesterol levels are 40-50% higher in highly active adults compared to inactive adults. Thus, the observation in this study that MVPA was related to high-risk HDL-cholesterol and triglycerides values, but not high-risk LDL-cholesterol values, is consistent with existing knowledge.

Kelley and Kelley completed a meta-analysis that included 12 randomized controlled trials looking at the effect of exercise training on plasma lipid levels in youth aged 8-16 years. They concluded that aerobic exercise training has no effect on non-
HDL-cholesterol (calculated as total cholesterol minus HDL-cholesterol) or on HDL-cholesterol.\textsuperscript{24} The lack of a significant effect of exercise training on plasma lipids in this meta-analysis may be partially attributable to the inclusion criteria. Specifically, this meta-analysis only included studies that recruited youth with normal pre-intervention lipid levels. Previous findings in adults have suggested that physical activity interventions are most effective at improving plasma lipids in those with abnormal lipid values pre-intervention.\textsuperscript{25-27} Our study focused on predicting high-risk plasma lipid values, and with this analytical approach we were able to demonstrate relations between MVPA with HDL-cholesterol and triglycerides.

We are aware of only two previous studies that have examined the dose-response relation between physical activity and plasma lipids in children and youth. Tolfrey and colleagues published the results of a 12 week intervention study that was conducted on a small sample (n=36) of 10-12 year olds.\textsuperscript{13} Participants were prescribed either low (~60 min/week) or moderate (~78 min/week) volume exercise programs. Not surprisingly, given the small total volume of exercise prescribed, and the small difference (~18 min/week) in exercise volume between the groups, the researchers failed to find a dose-response or threshold effect of physical activity on total cholesterol, LDL-cholesterol, HDL-cholesterol, or triglycerides. The second study was a cross-sectional study of 2358 young Finns aged 9-24 years.\textsuperscript{28} Participants were divided into tertiles based on their level of self-reported MVPA. Plasma triglyceride and HDL-
cholesterol levels improved across physical activity tertiles in this study. Although the results from this study suggested that a dose-response relation between MVPA and plasma lipids existed, the pattern of the dose-response relation (e.g., linear, curvilinear) was not adequately explored. Only 3 physical activity categories were compared, and each of these categories included a wide range of physical activity scores. Unlike the present study, where MVPA was examined on a continuum, this made it impossible for the authors to determine if there was a specific activity threshold where the cardiovascular risk factors improved.

To our knowledge, this is the first study to use both a large, representative study sample and an objective measure of physical activity to examine the relation between MVPA and plasma lipids in youth. Accelerometers provide a reliable and objective measure of physical activity in a ‘real-life’ setting. A limitation in previous observational studies is that information on level and intensity of physical activity was often obtained through subjective, self-report questionnaires. It is well documented that most children and youth over-report their time spent engaging in physical activity. Over-reporting of physical activity may have masked the true relationship between physical activity and lipid/lipoprotein level in the past. In other words, youth who self-reported as being ‘active’ and yet had an unfavourable lipid profile may have in reality been considered to be ‘inactive’ if physical activity had been measured objectively. The statistical modeling approach used in this current research has also allowed us to use
the model which best represented the relation between MVPA and high-risk plasma lipid values producing dose-response curve that best represent the data.

As with any study, the present study has a number of limitations. The primary study limitation is that it is observational and cross-sectional in nature. This limits our ability to make any causal inferences about the relation between MVPA and plasma lipids. Furthermore, although accelerometers are objective in nature and have been validated in previous population research,\textsuperscript{30} they are not a perfect measure of physical activity. Accelerometers are an insensitive measure when body movement in the hip region is independent of physical activity intensity (such as weight lifting or bicycling).\textsuperscript{31} Finally, it is important to note that this study only examined the relation between MVPA and the traditional plasma lipids. We did consider emerging lipid and lipoprotein risk factors, such as apolipoprotein B and small dense LDL particles. Nonetheless, the available information suggests that the relation between physical activity and apolipoprotein B in adolescents is similar to that between physical activity and LDL-cholesterol.\textsuperscript{32}

In conclusion, this study has helped to clarify the dose-response relation between MVPA and lipid/lipoprotein levels in youth. Although MVPA was not related to LDL-cholesterol, there were substantive reductions in the likelihood of having high-risk HDL-cholesterol and triglyceride values with even modest amounts of MVPA (e.g., ~5 min/d). The greatest reduction in the odds for high-risk values occurred within the first
30 min/d of activity. Because youth can achieve significant cardiovascular health benefits with even modest amounts of MVPA, physical activity guidelines for youth may need to recognize that getting youngsters to engage in less than the currently recommend ≥60 min/day of MVPA is beneficial. This is an important message given that three quarters of youth in this study did not even accumulate 30 min of MVPA on the average day. A minimal MVPA target of 30 min/day may act as a stepping stone for currently sedentary children, who upon reaching this stepping stone, could be encouraged to strive for the recommend ≥60 min/day.
Acknowledgements: The authors would like to thank Mr. Eric Bacon for his assistance with the data management and statistical analysis.

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Disclosures: None.
3.6 References


CHAPTER 4

DIFFERENCE BETWEEN SELF-REPORTED AND ACCELEROMETER MEASURED
MODERATE-TO-VIGOROUS PHYSICAL ACTIVITY IN YOUTH

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68
4.1 Abstract

**Objective:** The objectives of this study were to: 1) quantify the magnitude of the difference between self-report and accelerometer measures of MVPA in youth; 2) determine whether the difference between measures varies across the MVPA spectrum; and 3) determine whether the difference between measures is influenced by sex, age, or race.

**Participants:** The study sample consisted of 2761 youth aged 12-19 years from the 2003/2004 and 2004/2005 U.S. National Health and Nutrition Examination Survey. Self-report questionnaires gathered information about the frequency and average duration of MVPA (including transportation, school, and leisure-time) participants engaged in over the previous 30 days.

**Measurements:** Objective measures of MVPA were obtained over 7 days using Actigraph accelerometers. A series of linear regression models were used to determine relationships between self-report and objective measures of MVPA.

**Results:** Within each gender and racial subgroup, self-report and objective measures of MVPA were significantly but poorly correlated ($R^2 = 0.01$ to 0.10, $P<0.01$). Self-reported MVPA values were higher than objective measures (median values of 42.38 versus 15.00 min/d) such that 75% of the participants over-reported their MVPA by at least 5 minutes. The difference between self-reported and objective MVPA measures was not influenced by sex, age, or race ($P>0.1$). There was a systematic difference between self-
report and objective MVPA measures such that inactive participants over-reported their MVPA to the greatest extent.

**Conclusion:** The majority of youth over-reported the amount of time they spent engaging in MVPA. These findings may reflect a social desirability bias and/or a misunderstanding of what constitutes MVPA.

**Key words:** physical activity, accelerometer, self-report, adolescence, youth
4.2 Introduction

Regular participation in moderate-to-vigorous intensity physical activity (MVPA) is associated with many health benefits in young people such as a decreased likelihood of obesity,\textsuperscript{1} an increased positive self-concept,\textsuperscript{2} and a more favourable cardiometabolic disease risk factor profile.\textsuperscript{3,4} Traditionally, observational studies in the physical activity sciences have assessed MVPA in a subjective manner, such as by self-reported questionnaire.\textsuperscript{5} However, researchers are increasingly relying on objective physical activity measures, such as those obtained by pedometer and accelerometer, even with larger epidemiological studies.\textsuperscript{6} Therefore, to put the emerging literature into historical context, it is essential to appreciate the difference between perceived (e.g., subjective reports) and actual (e.g., objective reports) so that physical activity guidelines and recommendations can be adjusted accordingly.

A recent systematic review by Adamo et al.,\textsuperscript{7} highlighted the discrepancies between self-reported and objective measures of MVPA within the pediatric population. Of the 83 studies reviewed, 72% found that children and youth significantly over-reported their MVPA. A careful examination of the studies included within this systematic review highlights key limitations in the existing literature and raises some additional questions. First, the previous studies were based on relatively small and homogeneous samples. Thus, it is unclear as to whether the difference between self-reported and objective measures of MVPA varies according age, sex, and race. Second,
it is unknown as to whether the difference between self-reported and objective measures of MVPA varies across the physical activity scale. In other words, do both inactive and active youth over-report their level of physical activity, or is this issue limited to inactive youth?

There were three objectives addressed in this study: 1) to quantify the magnitude of the difference between self-reported and objectively measured MVPA, 2) to determine whether the difference between self-reported and objective measures varied across the MVPA spectrum, and 3) to determine whether the difference between self-reported and objective measures was influenced by sex, age, or race.

4.3 Methods

Data source

The current analysis consisted of 12-19 year old adolescents from the 2003/2004 and 2005/2006 cycles of the National Health and Nutrition Examination Survey (NHANES). More information pertaining to NHANES survey methodology can be found in Appendix C. Briefly, NHANES is a representative cross-sectional survey of the United States. Participants were identified using a complex stratified, multistage probability sampling design. NHANES included a home interview and a physical exam that was completed in a mobile exam centre. Informed consent was obtained from all participants and their parents or guardians if under the age of consent (Appendix D).
The study protocol was approved by the National Center for Health Statistics. The secondary analysis presented here was approved by the Queen’s University Health Sciences Research Ethics Board (Appendix E).

From the 4591 eligible participants, 2761 (1428 boys and 1333 girls) had both self-reported and objective measures of MVPA and were considered in the analyses (table 4.1).

**Table 4.1** Descriptive characteristics of subjects (n=2761)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Number</th>
<th>Proportion (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1428</td>
<td>51.7</td>
</tr>
<tr>
<td>Female</td>
<td>1333</td>
<td>48.3</td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Hispanic White</td>
<td>713</td>
<td>25.8</td>
</tr>
<tr>
<td>Hispanic</td>
<td>982</td>
<td>35.6</td>
</tr>
<tr>
<td>Non-Hispanic Black</td>
<td>958</td>
<td>34.7</td>
</tr>
<tr>
<td>Other</td>
<td>108</td>
<td>3.9</td>
</tr>
<tr>
<td><strong>Age (yr)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12-14</td>
<td>1084</td>
<td>39.2</td>
</tr>
<tr>
<td>15-16</td>
<td>689</td>
<td>25.0</td>
</tr>
<tr>
<td>17-19</td>
<td>988</td>
<td>35.8</td>
</tr>
</tbody>
</table>

**Objectively measured physical activity by accelerometry**

Physical activity was monitored objectively using Actigraph AM-7164 accelerometers (Actigraph, Ft. Walton Beach, FL, USA). Actigraph AM-7164
accelerometers are uniaxial monitors that measure vertical accelerations between 0.05-2.00 G in magnitude and at a frequency of 0.25-2.50 Hz. These parameters reduce spurious data caused by vibrations from outside sources and restrict monitoring to normal human movement. The filtered movement was stored as an activity count for one minute ‘epoch’ intervals. More information regarding the measurement of physical activity by accelerometer can be found in Appendix F.

Accelerometers were given out at the completion of the mobile exam center exam and were programmed to begin recording at 12:01 a.m. the following day. Participants were given an information pamphlet for additional information on how the accelerometers worked and proper care instructions (Appendix G). Monitors were worn for a 7 consecutive days and attached with an elastic belt to the right hip. Thus, for each participant there were 10,080 epoch values (one for each minute of the week), with each of these values corresponding to their intensity of movement during that minute. Participants were asked to wear their accelerometer during all waking hours, except when it would get wet (e.g., water sports, showering/bathing).

The 10,080 epoch values were downloaded from the accelerometers by the Centers for Disease Control and checked for biologically implausible data. Additional data reduction was completed by the authors before analyses. Specifically, participants were only included in the analyses if they had complete monitoring data for at least 4 days, including at least one weekend day. Days are considered complete if there is at
least 10 hours of monitoring time.\(^9\) Periods of 20 minutes or more of zero counts were assumed to indicate non-wear time and did not count towards the total wear time. Within adolescents, four days of physical activity monitoring using accelerometers has a test-re-test reliability correlation coefficient of 0.70.\(^9\)

An epoch threshold of $\geq 3000$ counts/minute was used to denote those minute where the participants were engaged in MVPA.\(^{10}\) This threshold is based on previous validation studies conducted in a similar age group and corresponds to a metabolic equivalent (MET) value of 3.0 (e.g., brisk walking).\(^{11}\)

For each complete day of monitoring, data was filtered to determine the number of minutes spent engaged in: 1) bouts of MVPA ($\geq 5$ minutes), and 2) sporadic MVPA (<5 minutes). Total MVPA for each day was then calculated as the sum of bouts and sporadic activity. Total minutes of MVPA were then averaged over the 4-7 day monitoring period to create a final variable for each participant that reflected their average MVPA in minutes per day.

**Self-reported physical activity by interview**

MVPA was measured subjectively through self-report. Participants were interviewed about specific activities they had engaged in over the past 30 days. This included activities performed in leisure time, at school, and for transportation (e.g., walking, biking). For each activity that they reported engaging in, participants were queried about the frequency, typical intensity, and typical duration. If the frequency
and duration of a single activity was implausible (i.e., over 12 hours/day) the time was assumed to be an error and was set as a missing value within the database. Time spent being physically active of a least a moderate intensity was summed to create a total amount of time (in minutes) spent engaging in MVPA over the past 30 days. This value was then converted to give an average minutes per day of MVPA. Moderate intensity activity is equivalent to brisk walking and calculated by a value of at least 3 METs.\textsuperscript{12} MET intensities were based on the Compendium of Physical Activity developed by Ainsworth et al. and calculated by NHANES representatives.\textsuperscript{12,13} To assure that the questionnaires and accelerometers measured the same activities, all water activities (fishing, kayaking, rowing, swimming, and surfing) were removed from the self-reported physical activity files prior to analysis.

\textbf{Statistical analysis}

All statistical analysis was performed using SAS version 9.1 (SAS Institute, Cary, NC) and took into account the sample weights and clustered nature of the NHANES survey. Both the objective and self-reported physical activity measures were positively skewed and were log transformed prior to regression analyses. Initially, descriptive statistics were performed. Paired t-tests were used to compare the means of the objective and self-reported MVPA measures. A chi-square test was used to determine the difference in the proportion of youth meeting physical activity guidelines (≥60 minutes per day\textsuperscript{14}) according to the objective and self-reported MVPA measures.
Demographic information on race (non-Hispanic white, non-Hispanic black, Hispanic, and other), age (to the nearest month), and sex were examined as effect modifiers. General linear models were run using the PROC SURVEYREG command to determine if the relationship between measures of MVPA was modified by age, sex, and race. Various models were run to determine if there was a statistical change in the relation between self-reported and accelerometer measured MVPA when different demographic variables were added to the regression equation.

Bland Altman plots were used to further explore the nature of the relationship between MVPA measures. Bland Altman plots, as opposed to correlation, report on how close the linear relationship is by plotting the level of agreement between two measurements. This is done because two methods can have a high correlation (i.e. a strong linear component) without actually agreeing on the measurements. Finally, by plotting the difference between measures of self-reported and accelerometer measured MVPA, we determined if the difference between objective and self-reported measures was systematic in nature.

4.4 Results

Descriptive information

Basic descriptive information on the study sample is shown in table 4.1. Details on the physical activity measures are shown in table 4.2. The median time engaged in
MVPA was 15.0 min/d based on accelerometer measures and 42.4 min/d based on self-reported measures. The median difference between the two measures was 27.4 min/d (P<0.001) with self-reported measures over-reporting MVPA by 182.5%.

**Table 4.2** Summary of moderate-to-vigorous physical activity measures

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Median in min/d (mean ± SD)</th>
<th>Meeting 60 min/d Guideline (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objective (accelerometer)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>15.0 ± 19.9</td>
<td>2.3</td>
</tr>
<tr>
<td>Boys</td>
<td>23.4 ± 21.9</td>
<td>4.2</td>
</tr>
<tr>
<td>Girls</td>
<td>9.3 ± 13.3</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Self-report (questionnaire)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>42.4 ± 102.8</td>
<td>37.9</td>
</tr>
<tr>
<td>Boys</td>
<td>56.9 ± 111.3</td>
<td>45.8</td>
</tr>
<tr>
<td>Girls</td>
<td>32.0 ± 90.8</td>
<td>29.8</td>
</tr>
</tbody>
</table>

Most youth (65.4%) over-reported their time spent engaging in MVPA by at least 5 minutes. Twenty percent of youth under-reported their time spent engaging in MVPA by at least 5 minutes. In the remaining 14.6% of participants, the objective and self-reported measures were within ± 5 minutes. Significantly fewer youth met international physical activity guidelines (≥60 min/d) based on objective measures of MVPA compared to self-reported measures (2.4% versus 37.9%, P<0.001).

**Relation between objective and self-reported measures of physical activity**

Within the entire subject pool, the objective and self-reported measures of MVPA were poorly but significantly correlated (R²=0.04, P<0.001). As illustrated in fig
4.1 panel A, the intercept of the regression line between the objective and self-reported MVPA measures was greater than 0 (P<0.0001) and the slope was less than 1 (P<0.0001). This indicates that the difference between the objective and self-reported MVPA measures was systematic in nature such that those at the low end of the physical activity scale tended to over-report their MVPA to a greater extent than moderately activity participants, while highly active participants tended to under-reported their MVPA. Systematic differences between the objective and self-reported measured MVPA were further explored using a Bland-Altman Plot (fig 4.1 panel B). Analysis revealed that the average difference between the objective and self-reported MVPA measures was significant (P<0.001). The Bland-Altman plot also shows a small but significant negative relation ($R^2=0.22$, P<0.001) between the difference in objective and self-reported measures of MVPA, further illustrating the systematic nature of the
Figure 4.1 *Panel A*: difference between self-reported and accelerometer MVPA in boys, girls, and for the total sample (youth 15 years of age). Dotted line represents line of identity which shows values if there was no difference between self-reported and accelerometer measurements. *Panel B*: Bland Altman plot showing difference between MVPA as measured by self-report questionnaire and accelerometer vs. average MVPA measured by the two methods for all subjects. Solid line, regression line; dotted line, average difference between the two methods; dashed line, 95% confidence interval for difference.
Sex, age, and ethnic differences

Within each of the sex and ethnic subgroups, the objective and self-reported measures of MVPA were poorly correlated ($R^2=0.02$ in boys, $R^2=0.04$ in girls, non-Hispanic white $R^2=0.04$, Hispanic $R^2=0.09$, and non-Hispanic black $R^2=0.06$). The relation between the objective and self-reported MVPA measures was not significantly modified by sex (P>0.1, fig 4.1 panel A). In other words, the magnitude and direction of the differences between the objective and subjective measures of MVPA was not different in boys and girls. Similarly, the relation between objective and self-reported measures of MVPA was not significantly modified by age (P>0.2, fig 4.4 panel A) or race (P=0.7, fig 4.2 panel B).

4.5 Discussion

This study examined the relation between accelerometer and self-reported measures of MVPA in a large and representative sample of youth. Two thirds of the participants over-reported the MVPA by at least 5 min/day. Although the self-reported and objective measures of MVPA were poorly correlated, the results suggest that over-reporting of MVPA was particularly problematic in inactive youth. The nature of the self-report bias was not influenced by sex, age, or race.
The observation that youth over-reported their MVPA is consistent with a large body of evidence that has recently been synthesized in a systematic review.\(^7\) The studies in this systematic review consistently reported low-to-modest correlations between self-reported and accelerometer measured physical activity with self-report measures overestimating activity in children and youth.\(^7\) Self-reported measures of MVPA overestimated accelerometry measures by an average of 147%. Within the present study we observed weak correlations between self-reported and accelerometer

![Figure 4.2 Panel A: difference between self-reported and measured MVPA in youth 12, 15, and 19 years of age. Panel B: difference between self-reported and measured MVPA with respect to race for youth 15 years of age. Dotted line represents line of identity which shows values if there was no difference between self-reported and accelerometer measurements.](image-url)
measures of MVPA. Self-reported MVPA was over-estimated by an average of 183%.

These findings are consistent with the findings reported in the systematic review.\cite{7}

Past studies examining the relationship between self-reported and objectively measured MVPA in youth have relied on small and homogeneous samples.\cite{7} There have been limited attempts to determine whether key demographic characteristics (age, sex, race) influence the self-reporting bias. McMurray et al,\cite{16} reported that girls over-reported their MVPA to a greater extent than boys, while Mota et al,\cite{17} reported the opposite. In the present study we found no difference in the nature of the self-reporting bias in boys and girls. Past research provides limited insight as to whether the miss-reporting of MVPA is consistent in children and youth of different ages. Mota et al,\cite{17} found that the correlations between self-report and accelerometer values of physical activity were slightly higher in older children (>10 years) than in younger children (8-16 years). In this study we found no difference in the amount of over-reporting across different ages. To our knowledge, no previous studies have examined whether race influences the degree of over-reporting of MVPA in youth. Most of the research in this area has been conducted in predominately white population groups.\cite{7,18-20} The limited research conducted in minority groups has also found that there is a tendency for MVPA to be over-reported.\cite{17,21,22} The findings from the current research suggest that the nature and extent of over-reporting is not modified by race.
Social desirability bias and a misinterpretation of the level of perceived exertion may account for some of the discrepancy between self-reported and objective measures of MVPA. Social desirability bias describes the tendency for respondents to distort their answer towards the more socially acceptable and desirable behavior. Klesges and colleagues found that youth with higher levels of social desirability, measured using a modified version of the Children’s Manifest Anxiety Scale, over-reported their physical activity to the greatest extent. Misinterpretation of the level of perceived exertion during a bout of physical activity may also lead to over-reporting of MVPA. In particular, children and youth that have a history of uncomfortable experiences during exercise are more likely to have higher perceptions of their levels of exertion. This may lead to a skewed perception of time and intensity spent engaging in physical activity, resulting in over-reporting.

The manner in which children and youth accumulate their MVPA over the course of a day may account for some of the over-reporting and the poor relations between objective and subjective MVPA measures. Unlike physically active adults, who may accumulate most or all of their daily activity in a single session, children and youth tend to engage in short, sporadic bursts of activity (e.g., a couple of minutes of activity). These sporadic bursts may be difficult to quantify in a questionnaires. Mark and Janssen recently reported that sporadic sessions of MVPA, defined as physical activity session less than 5 minutes in length, accounted for 66% of total daily MVPA in children.
and youth. Thus, youth may be inadvertently over-reporting their time spent being physically active by considering many separate sporadic bursts of activity as one longer bout. The information from the present study could be used to develop public health messages that account for misinterpretations youngsters may have about the true volume of MVPA that is needed for health and their own activity levels. Because most youth over-report their time spent being active, with an average over-reporting of close to 30 minutes per day, physical activity guidelines may need to be adjusted accordingly. That is, if youth need to accumulate 60 min/d of MVPA to achieve significant health benefits, public health messages may need to recommend 90 min/d of MVPA to adjust for differences in perceived and actual levels of activity.

As with any study, the present study has a number of limitations. Although accelerometers are objective in nature, they are not a perfect measure of physical activity. Accelerometers are an insensitive measure when body movement in the hip region is independent of physical activity intensity (such as weight lifting or bicycling). There are also discrepancies amongst researchers as to the appropriate accelerometry thresholds that define MVPA. If different thresholds were used, the overall volume of objectively measured MVPA would have changed. Limitations associated with self-report questionnaires are discussed throughout this paper. It should also be noted that the questionnaire used asked about activities that the participant engaged in over the past 30 days, whereas accelerometers measured activities in the week following the
mobile exam center visit. The lack of congruency between measurement time periods for the self-reported and objective MVPA measures may account for some of the observed differences.

In conclusion, this study has helped clarify the relationship between self-reported and objective measures of MVPA in 12-19 year old youth. While the relationship between self-reported and objectively measured MVPA was not influenced by basic demographic characteristics (sex, age, and race), the issue of over-reporting was particularly problematic in inactive youth. These findings may reflect a social desirability bias, a misunderstanding of what constitutes MVPA, and the sporadic nature in which inactive children accumulate their activity. Public health messages around the appropriate volume of MVPA may need to account for discrepancies between perceive and actual activity levels.
Acknowledgements: None

Funding: This study was supported by an operating grant provided by the Canadian Institutes of Health Research (MOP 84478). Ian Janssen is supported by a New Investigator Award from the Canadian Institutes of Health Research and an Early Researcher Award from the Ontario Ministry of Research and Innovation.

Competing interests: None.
4.6 References


CHAPTER 5

GENERAL DISCUSSION, SUMMARY OF FINDINGS, AND CONCLUSIONS

5.1 Summary of key findings

The overall purpose of this thesis was to explore dose-response relation between physical activity and health within school-aged children and youth, with the hope of providing results that will be helpful in developing improved physical activity guidelines and recommendations for young people. Specifically, the first manuscript attempted to develop a better understanding of the amount of MVPA needed to reduce the risk of dyslipidemia in youth aged 12-19 years. It was determined that there was an inverse curvilinear relationship between MVPA with high-risk HDL-cholesterol and triglyceride levels. The greatest change in risk for dyslipidemia occurred within the first 20-30 minutes of MVPA. This suggests that current physical activity guidelines for youth (60 min/day of MVPA\(^1\)) may be recommending a higher volume of activity than is needed to achieve substantive health benefits. Therefore, it is suggested that physical activity guidelines should consider including a minimum (30 min/day) and an optimal (60 min/day) target. Setting both a minimal and an optimal target for daily physical activity has been suggested in past reviews of physical activity guidelines\(^2\) and is already
incorporated into the recommendations of some organizations. Setting a minimum threshold for activity may be ideal for children who are currently inactive and may be discouraged by the large volume of physical activity that is currently recommended. Thus, 30 min/day of MVPA may act as a ‘stepping stone’ for inactive children and youth.

The second manuscript aimed to quantify the difference between subjective (i.e., self-report) and objective (i.e., accelerometer) measures of MVPA in youth. Two thirds of the participants over-reported their MVPA by at least 5 min/day, with the median amount of over-reporting approaching 30 min/day. This relationship was systematic in nature such that inactive youth over-reported their activity to the greatest extent. However, the level of over-reporting was not influenced by sex, age, or ethnicity. This information will be useful when setting recommended physical activity levels for public health guidelines. That is, physical activity recommendations may need to be adjusted to account for differences between perceived physical activity and the true volume of physical activity that is needed for good health (i.e., recommend a higher level of physical activity than is needed).

5.2 Limitations

There are limitations common to both studies included in this thesis that warrant discussion. First, all analyses were completed using data from a health and nutrition
survey representative to the U.S. population. It would have been ideal to use a Canadian dataset. Unfortunately, there are no comparable dataset available for Canadian youth. Nonetheless, previous epidemiological studies examining the relationship between physical activity and health have shown similar trends in their results, irrespective of the nationality and race of the study participants.\textsuperscript{4,5} Thus, it is unlikely that the relationships observed between MVPA and dyslipidemia in this thesis would be different in Canadian youth.

Both manuscripts used accelerometers as an objective measure of physical activity. Although the uniaxial accelerometers used in NHANES have been validated in the adolescent age group,\textsuperscript{6} they are not a perfect measure of physical activity. Briefly, uniaxial accelerometers are an insensitive measure when body movement in the hip region is independent of physical activity intensity (such as weight lifting or bicycling).\textsuperscript{7} There are also discrepancies amongst researchers as to the appropriate accelerometry thresholds that define MVPA.\textsuperscript{7,8} If different thresholds were used, it is possible that the overall volume of objectively measured MVPA would have changed. More information regarding the methodology and limitations associated with the use of the accelerometers can be found in Appendix F.

The primary limitation in the first manuscript relates to the cross-sectional nature of the NHANES dataset. This limits the ability to make causal inferences about
the relations between MVPA and plasma lipids. However, in addition to temporal sequence, other factors should be considered when determining the likelihood of causation within epidemiological research (e.g., Hill’s postulates), such as consistency of findings, strength and dose-response nature of the observed associations, and biological plausibility of the findings. The negative association seen between physical activity and dyslipidemia observed in this thesis is consistent with past research. Furthermore, the strength of the association between physical activity and reduced risk for high risk HDL-cholesterol and triglyceride values was strong, and followed a dose-response pattern. The findings are also biologically plausible as MVPA alters the activity of enzymes involved in the synthesis, transport, and catabolism of the various lipoproteins such as lipoprotein lipase and hepatic lipase. Changes in enzyme activity leads to a decrease in HDL-cholesterol immediately after exercise and a reduction in plasma triglycerides 18-24 hours after exercise. The effect of physical activity on LDL-cholesterol metabolism is not as clear.

It is also important to note that this manuscript only examined the traditional lipids that are measured in clinical practice. There are a number of emerging lipids and lipoprotein markers that are independent risk factors for cardiovascular disease including apolipoprotein B, apolipoprotein A, very-low-density lipoprotein cholesterol, and small dense LDL particles. Previous research examining the influence of physical
activity on these emerging lipid and lipoprotein markers has been primarily conducted in the adult population. Evidence in adults suggests that physical activity may have a positive effect on some of these markers.\textsuperscript{14} Future research needs to consider the effect of physical activity on emerging cardiovascular disease risk factors in the pediatric population.

The main limitations in the second manuscript also relate to the NHANES survey methodology. The self-report questionnaire inquired about activities that the participants engaged in over the past 30 days. Conversely, the accelerometers measured activities in the week following the mobile exam center examination. The lack of congruency between measurement time periods for the self-reported and objective measures of MVPA may have accounted for some of the observed differences between the two measures. However, because youth tend to have fairly low day-to-day variability in their activity levels,\textsuperscript{15} it is unlikely that the results would have changed significantly had the self-reported and objective measures of MVPA been obtained at the same time.

5.3 \textbf{Strengths}

To my knowledge, the first manuscript of this thesis is the first to use a representative study sample to examine the dose-response relation between physical
activity and dyslipidemia in youth. This study was also the first to examine these
relationships using an objective measure of physical activity. Furthermore, the
statistical modeling approach employed allowed me to determine the dose-response
curve that best represented the relation between MVPA and high-risk plasma lipid
values.

The second manuscript is the first study to use a large data set to describe the
difference between self-reported and objectively measured physical activity. Previous
studies have relied on small, homogeneous samples and have been unable to determine
if the level of over-reporting varies by age, sex, or ethnicity. Furthermore, to my
knowledge, the research in this thesis was the first determine whether the level of over-
reporting varies across the physical activity spectrum. Thus, two novel observations
were made in this thesis. First, the level of over-reporting of MVPA was not influenced
the major demographic characteristics. Second, the level of over-reporting was
systematic in nature such that inactive youth over-reported to the greatest extent.

5.4 Public health and policy implications

The results of the research conducted in this thesis suggest that youth who
accumulate any physical activity have a substantially lower risk for low HDL-cholesterol
and high triglycerides levels. Those who accumulate 20 to 30 minutes of MVPA per day
are 75% less likely to have unfavourable levels when compared to inactive youth. This volume of physical activity is substantially less than what is recommended in the current Canadian\textsuperscript{16,17} (90 min/day) and international\textsuperscript{18} (60 min/day) physical activity guidelines.

Although this research indicates that current physical activity guidelines for youth may be too stringent in their recommendations, the second manuscript in this thesis has demonstrated that there is a substantial difference between the perceived and actual amount of time that youth are engaging in MVPA. Thus, with respect to dyslipidemia in youth, physical activity guidelines may recommend lower levels of physical activity than what is currently suggested; however, there may need to be create separate public messages regarding physical activity to accompany these guidelines to account for the altered perception youth have about their current level of activity. In other words, since 30 min/day of MVPA may be needed to decrease a young person’s risk of dyslipidemia, and since the average young person who accumulates 30 min/day of MVPA believes they are accumulating 60 minutes, it may be appropriate to set physical activity guidelines for good health at 30 min/d but accompany these guidelines with public health messages that may suggest as much as 60 min/day for optimal health. Further research is required to properly frame these health messages but would need to include information on such things as the importance of ‘rest-periods’ during different bouts of activity. Coincidentally, with the exception of Canada’s physical activity
guidelines for children and youth,\textsuperscript{16,17} numerous countries and organizations recommend that children and youth accumulate 60 minutes of MVPA on a daily basis.\textsuperscript{1,3,10}

5.5 Future research directions

Future research is needed to increase our understanding of the dose-response relation between physical activity and other health outcomes that are relevant for youth such as insulin resistance, the metabolic syndrome, bone density, and markers of mental health. Additionally, there is little information on the health benefits that may occur from participating in a variety of activities. In other words, from a health perspective, is it acceptable for a young person to concentrate their efforts in one sport, or would they receive additional benefits from ‘cross-training’ and participating in many sports and activities. Furthermore, it is unclear if children and youth need to be active on a daily basis (i.e., accumulate 60 minutes every day), or if they can accumulate a comparable amount of activity over a few days during the course of the week (i.e., accumulate 7 hours in a week). Finally, although it is important to understand the impact of MVPA, it is important to remember that even the most active youth are only active for an hour or two on a typical day, and that a far greater percentage of their time is spent being sedentary. Future research should focus on understanding the effect of different sedentary behaviours (i.e., television vs. video games vs. reading) on health.
outcomes. Recent research has suggested that MVPA and television viewing are independent predictors of poor health outcomes,\textsuperscript{19} but the association with other sedentary behaviours is unclear.\textsuperscript{20}

5.6 Conclusions

The research in this thesis has helped to clarify the dose-response relation between MVPA and plasma lipid levels in 12-19 year old youth. Furthermore, this research has quantified the discrepancy between self-reported and objectively measured MVPA in youth. Although the results of this thesis support current public health recommendations of a high volume of MVPA (i.e., 60 min/day), they also suggest that youth can achieve significant health benefits with far less physical activity (i.e., 20-30 min/day).
5.7 References


Appendix A

Lipids and Lipoproteins
Lipids and Lipoproteins

Overview

Cholesterol is a water-insoluble molecule that requires lipoproteins to act as its transport molecules to move exogenous and endogenous lipids between the liver, intestines, and peripheral tissues. Lipoproteins are macromolecular structures composed of lipid and protein molecules; the higher the lipid-to-protein ratio of the molecule, the lower its density. Lipoproteins are commonly classified as a high-density lipoproteins (HDL) or low-density lipoproteins (LDL) molecules.

LDL-cholesterol: LDL is the largest transport molecule and LDL-cholesterol makes up the majority of total cholesterol. LDL-cholesterol is atherogenic and plays a causative role in cardiovascular disease by transporting cholesterol away from the liver and back to the peripheries. The lipid portion of the molecule has a tendency to oxidize allowing the cholesterol to enter the arterial wall leading to blockages in blood flow.

HDL-cholesterol: HDL-cholesterol is anti-atherogenic and is the central mechanism to enhance the reverse transport of cholesterol from the periphery to the liver. Once in the liver, cholesterol is then excreted. HDL-cholesterol also acts as an anti-inflammatory agent preventing oxidation of LDL-cholesterol.

Triglycerides: Triglycerides are the most common form of fat found in our diet and the main storage form of fat in the body. Plasma triglycerides are water-insoluble
molecules and transported through the bloodstream via very low-density lipoproteins. Once in the body, triglycerides are broken down and absorbed into the intestinal wall. If the fatty acid portion of the triglyceride is either short or medium chain (C-10 or less) they pass directly through the intestinal cell and are carried directly to the liver to be excreted as waste. If it is composed of long-chain fatty acids then they are generally re-esterfied into a triglyceride inside the intestinal cell for further metabolism until it can be returned to the liver to be metabolized.4

**Relation between lipid/lipoprotein levels and cardiovascular disease risk**

The harmful effects of cholesterol are seen when the lipoprotein transport molecule deposits cholesterol onto blood vessel walls increasing a person’s risk for developing atherosclerosis. Atherosclerosis is the primary underlying disease leading to CVD and develops when lipid deposits increase plaque build-up and eventually reduces or blocks blood flow.5 Research has consistently shown that a reduction in total plasma lipid and lipoprotein levels results in a reduced risk for cardiovascular disease.6 For example, findings from the Lipid Research Clinic Coronary Primary Trial suggest that each 1% reduction in serum total cholesterol results in a 2% decrease in risk of CVD.7,8

Levels of HDL-cholesterol are generally the strongest predictor of coronary heart disease with higher levels consistently associated with decreased risk for CVD.9,10 HDL-cholesterol acts as a cardioprotective factor and the risk for coronary heart disease
continues to decrease as levels of HDL-cholesterol increase.\textsuperscript{11} Increased levels of plasma triglycerides have been associated with decreased levels of HDL-cholesterol in youth.\textsuperscript{12} Furthermore, a direct and graded relationship between the severity of heart disease and the level of plasma triglycerides has been reported in adults.\textsuperscript{13}

**Tracking of plasma lipid and lipoprotein profiles from childhood to adulthood**

Increasing attention is being paid to unfavourable lipid and lipoprotein profiles in youngsters for two main reasons. First, it is now clear that the process of atherosclerosis begins in childhood.\textsuperscript{13-16} Second, children and youth with abnormal lipid and lipoprotein levels are more likely to have abnormal values in young adulthood.\textsuperscript{13-16} LDL-cholesterol and triglyceride levels have shown to track well from childhood to early adulthood and were moderately stable throughout a 12 year tracking period.\textsuperscript{16} Further research suggests that although there is considerable variability in plasma lipids/lipoproteins throughout puberty and adolescence, there is a large tracking correlation from pre-pubescent groups to early adulthood.\textsuperscript{14} Those identified to have high-risk levels of LDL-cholesterol and HDL-cholesterol in childhood were about four times more likely to be in the same group in early adulthood.\textsuperscript{14} The identification of children and youth who are at increased risk for atherosclerosis could facilitate the management and aid in the prevention of related health problems later in life.
References


Appendix B

Age- and Gender-Specific Lipid and Lipoprotein Cut-Points
<table>
<thead>
<tr>
<th>Age§</th>
<th>HDL-C</th>
<th>LDL-C</th>
<th>TG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low (26th)</td>
<td>Protective (13th)</td>
<td>Above Normal (54th)</td>
</tr>
<tr>
<td>12</td>
<td>1.13</td>
<td>1.70</td>
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<td>1.10</td>
<td>1.64</td>
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<tr>
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<td>2.39</td>
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<td>2.56</td>
</tr>
<tr>
<td>20</td>
<td>1.04</td>
<td>1.55</td>
<td>2.59</td>
</tr>
</tbody>
</table>

*to convert LDL-C, HDL-C (mmol/L) to mg/dL, multiply by a factor of 38.67. To convert TG (mmol/L) to mg/dL, multiply by a factor of 88.5.

§ cut-points represent the mid-point of the one-year increment and can be used for individuals within the 1-year age range.

Table 2. Age-specific lipoprotein cut-points (mmol/L)* and corresponding percentiles for females

<table>
<thead>
<tr>
<th>Age §</th>
<th>HDL-C</th>
<th>LDL-C above 54th</th>
<th>LDL-C borderline-high 86th</th>
<th>LDL-C high 98th</th>
<th>TG borderline-high 89th</th>
<th>TG high 95th</th>
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<tr>
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<td>3.52</td>
<td>1.60</td>
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<td>2.59</td>
<td>3.37</td>
<td>4.14</td>
<td>1.70</td>
<td>2.26</td>
</tr>
</tbody>
</table>

*to convert LDL-C, HDL-C (mmol/L) to mg/dL, multiply by a factor of 38.67. To convert TG (mmol/L) to mg/dL, multiply by a factor of 88.5.

§cut-points represent the mid-point of the one-year increment and can be used for individuals within the 1-year age range

Appendix C

National Health and Nutrition Examination Survey
National Health and Nutrition Examination Survey

Background

The goal of the National Health and Nutrition Examination Survey (NHANES) is to monitor the overall health of the U.S. population; a more comprehensive outline of the goals can be found on the NHAES website: (http://www.cdc.gov/nchs/tutorials/NHANES/SurveyOrientation/SurveyOverview/Info1.htm).

NHANES began as the National Health Examination Survey (NHES) in 1960 and was expanded to include a nutrition component in 1971. Since that time there have been significant improvements in the way in which the information has been collected and organized, as well as with the technology used to collect and analyze this information. In 1999 the survey changed from a periodic review of health to a continuous bi-annual survey. Every two year cycle is a representative sample of the U.S. population. The continuous NHANES design also allows researchers to merge multiple survey cycles.

Design

NHANES is a representative cross-sectional survey of the United States. Participants were identified using a complex stratified, multistage probability sampling design. All civil, non-institutionalized U.S. citizens are eligible for inclusion.
Oversampling of African Americans, Mexican Americans, low-income White Americans, adolescents (age 12-19), and persons >60 years is done to increase the reliability and precision of health indicators for these groups.

Sampling occurs in four stages. 1. Primary sampling units (PSUs) are selected. These are generally single counties. 2. The PSU is divided into smaller strata, generally the equivalent to a city block. 3. A random sample of households within this strata are then chosen. If there is a high proportion of minority groups (those selected for oversampling) within a given strata, then the probability that the minority group is selected is higher. 4. Based on a list of all persons residing in the selected households, individuals are then randomly chosen to participate in NHANES. On average, 1.6 persons from the selected household are asked to participate in NHANES. Each participant is then given a sample weight. A sample weight is a measure of the number of people in the population (based on the 2000 Census) that the participant is representing. This sample weight reflects the unequal probability of selection and an adjustment for non-response producing an unbiased national estimate.

**Survey Components**

NHANES is a two part examination including a home visit and a visit to a mobile exam center (MEC). At the home visit, a NHANES representative collects basic demographic information (e.g. age, race) and lifestyle characteristics (e.g. physical
activity, smoking) by questionnaire. At the home visit, the NHANES representative also arranges for the participant to visit the MEC. The MEC visit is a more comprehensive exam taking about 3 ½ hours to complete and covering a large range of health indicators. The MEC survey team is a specialized team of health care professionals including a physician, medical and health technicians, and dietary and health interviewers. During the MEC examination, participants complete additional interviewer-administered questionnaires (e.g. dietary questionnaires) and are given a physical activity monitor. Participants who complete the MEC examination are also asked to complete two follow up questionnaires over the telephone with a NHANES representative.

Survey Data

Survey data are presented by cycle (e.g. 2003-2004, 2005-2006) and topic (i.e. demographic, examination, laboratory, and questionnaire). All data can be found at: http://www.cdc.gov/nchs/nhanes.htm. Data files are freely available as a SAS export files and must be downloaded at the website. Each data file contains a related grouping of variables for a given cycle. For example, the “body measurements” data file contains measures of height, weight, skinfolds, and circumferences. Multiple data files can be merged together to link different sets of variables.
Appendix D

National Health and Nutrition Examination Survey: Consent Form
Print name of respondent

First                      Middle                      Last

You have been chosen to take part in the National Health and Nutrition Examination Survey (NHANES) conducted by the National Center for Health Statistics (NCHS). This survey tells us about the health and nutrition of people in the United States. It combines an interview with a health exam. Our interviewer will ask questions about you and your family. Some questions are about your work and leisure and your health care. Others are about illnesses and health conditions and other health topics. Also, we will ask for your Social Security and Medicare numbers for linkage to other data sources to do research on health and health care. The interview will take about one hour. We may contact you again for further studies.

We use data collected in this survey to study many health issues. We use information only for research and statistical reports. All data collected will be kept strictly private. We gather and protect all information in keeping with the requirements of Federal Laws: the Public Health Service Act (42 USC 242k) authorizes collection and Section 308(d) of that law (42 USC 242m) and the Privacy Act of 1974 (5 USC 552A) prohibits us from giving out information that identifies you or your family without your consent.

You may take part in the survey interview or not. That is your choice. No penalties or loss of benefits will come from refusing. If you choose to take part, you may choose not to answer any question.

Do you have more questions about the survey? You can make a toll-free call to Dr. Kathryn Porter of the U.S. Public Health Service at 1-800-452-8115, Monday-Friday, 8 AM-6 PM EST. If you have questions about your rights as a survey participant, call the Institutional Review Board Chairperson at 1-800-223-8118.

I have read the information above. I freely choose to participate in the NHANES household interview.

Signature of person answering household questionnaire(s)  Date

IF PERSON ABOVE IS 16 OR 17, PARENT/GUARDIAN MUST ALSO SIGN BELOW:
(Unless participant is an emancipated minor.)

Signature of parent/guardian  Date

Signature of staff member  Date  Witness (if required)  Date

HOUSEHOLD ID  __  __  __  __  __  __  __  __  __  __  FAMILY #: __  __

Which questionnaire(s) did person respond to?

FAMILY □  SP □  (IF CHECKED, PRINT BELOW)

SP NAME

SP ID

☐ I agree to have my interview audiotaped.

---

Public reporting burden of the collection of information is estimated to average 6.6 hours per response for total participation, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. An agency may not conduct or sponsor, and a person is not required to respond to collection of information unless it displays a currently valid OMB control number. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to CDC/ATSDR Reports Clearance Officer; 1600 Clifton Road, MS D-24, Atlanta, GA 30333, ATTN: PRA (090003257).
Appendix E

Queen’s University Research Ethics Approval
QUEEN'S UNIVERSITY HEALTH SCIENCES & AFFILIATED TEACHING HOSPITALS RESEARCH ETHICS BOARD

August 23, 2007

This Ethics Application was subject to:

☐ Full Board Review
Meeting Date:
☒ Expedited Review

Dr. Ian Janssen
Assistant Professor
School of Kinesiology and Health Studies, and
Department of Community Health and Epidemiology
Queen's University

Dear Dr. Janssen,

Study Title: Dose-response relation between physical activity and screen time behaviours with health in school-aged children

Co-Investigator: Dr. William Boyce, Social Program Evaluation Group, Faculty of Education

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

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

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

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

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

Yours sincerely,

[Signature]
Chair, Research Ethics Board

Study Code: EPID-244-07

➢ Investigators please note that if your trial is registered by the sponsor, you must take responsibility to ensure that the registration information is accurate and complete.
The membership of this Research Ethics Board complies with the membership requirements for Research Ethics Boards as defined by the Tri-Council Policy Statement; Part C Division 5 of the Food and Drug Regulations, OHRP, and U.S. DHHS Code of Federal Regulations Title 45, Part 46 and carries out its functions in a manner consistent with Good Clinical Practices.

Federalwide Assurance Number: #FWA00004184
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FACULTY OF HEALTH SCIENCES AND AFFILIATED TEACHING HOSPITALS DATA SHEET
FOR RESEARCH INVOLVING HUMAN SUBJECTS
To be completed only if the research involves the use of human subjects
Attach to Office Of Research Services, Research Data Summary And Signature Sheet

Ref: Ethics to Human Experimentation, Medical Research Guidelines 1997
Queen's University Health Sciences & Affiliated Teaching Hospitals Human Research Ethics Board Guidelines, 1993

Project Title: Dose-response relation between physical activity and screen time behaviours with health in school-aged youth

1. Human subjects will be required to participate: NO [ ] YES [ √ ]

2. The protocol has been submitted for ethics review: NO [ ] YES [ √ ]

3. If answer to 1 is "YES" and 2 is "NO", please explain: ____________________________

4. Does this research require the participation of hospital patients? NO [ ] YES [ √ ]

Circle hospital(s) concerned: KGH HDH SMOL KPH Other (specify) _______________________

5. Will hospital facilities be required for research involving human subjects? NO [ ] YES [ √ ]

Circle hospital(s) concerned: KGH HDH SMOL KPH Other (specify) _______________________

6. Will patients be selected from department other than your department of primary affiliation?
   If yes, your signature below indicates that you have received written consent from the
   Head(s) of hospital department(s) NO [ ] YES [ √ ] N/A [ √ ]

7. Do all research personnel having contact with patients have appropriate hospital
   Department appointments (i.e. staff, residents, departmental assistants)? NO [ ] YES [ √ ] N/A [ √ ]

8. Will research involve the use of hospital facilities over and above those required
   for normal patient care? NO [ ] YES [ √ ]

If "YES", indicate department: Cost Costs confirmed with (name of person)
Laboratory ____________________ ____________________
Nursing ____________________ ____________________
Pharmacy ____________________ ____________________
Radiology ____________________ ____________________
Other [please specify] ____________________ ____________________
TOTAL ____________________ ____________________

Are these costs included in the budget of the grant application? NO [ ] YES [ ] N/A [ √ ]
If not, how will they be paid for? ____________________________

Investigator [ ] Date [ ]
Department Head [ ] Date [ ]

Chair, Research Ethics Board

123
Appendix F

Measuring Physical Activity in Youth
Measuring physical activity in children and youth

Overview

Due to their ease of use and overall feasibility, population based research has often relied on indirect tools to measure physical activity. Physical activity questionnaires are generally completed via a self-reporting of behavior or through a proxy measure if the participant is unable to answer for themselves. However, there is concern questioning the validity of self-report measures, especially in the pediatric population. Children and youth tend to over-estimate their time spent being active either through a misunderstanding of what is considered moderate-to-vigorous physical activity\(^1\) or by a social desirability bias.\(^2\)

Researchers are increasingly relying on objective physical activity measures, such as those obtained by pedometer and accelerometer.\(^3\) Direct measures of physical activity include direct observation, doubly labeled water, heart rate monitoring, and activity (accelerometry) monitors. Doubly labeled water is considered the ‘gold standard’ measurement regarding energy expenditure; however, it is costly and difficult to administer on a population level. Furthermore, it is a measure of total energy expenditure and not physical activity per se. Direct observation techniques are well suited to studies looking at children and youth due to their sporadic levels of physical activity. However, direct observation can be costly and obtrusive.\(^4\) Heart rate monitors
are relatively feasible for large studies and can provide information on a variety of parameters; however, due to the numerous other factors that can influence resting heart rate, researchers are cautioned when using heart rate monitors for an extended period of time.\textsuperscript{5} Furthermore, heart rate response tends to lag momentarily behind change of movement and remain elevated after the movement is finished; this limitation may mask the sporadic nature of physical activity in young people.\textsuperscript{5} Activity monitors (i.e. accelerometers, pedometers) are becoming increasingly available, even for large, epidemiological studies.

Pedometers are small and unobtrusive to the participant, they are feasible for large studies, and have been validated in previous research.\textsuperscript{6} They do not have the ability to record duration, frequency, or intensity of activity and therefore only provide the researcher with a measure of the total volume of physical activity.\textsuperscript{6} Therefore, although pedometers are extremely feasible for large studies, they are limited in the information they are able to provide.

Accelerometers are small devices that use pizo-electric monitoring to calculate vertical accelerations of an individual; these accelerations are then used to calculate the individual’s volume and intensity of physical activity. Although accelerometers are generally more expensive than pedometers, they provide far more information. A review by Bjornson highlighted nine accelerometers validated to be used in population
studies. Six of the monitors included in the review have been previously validated to be used within the pediatric population. Of the devices included in the review, the majority were unidimensional and attached at the hip or ankle. Cost of these monitors varied a great deal but was reported between $100 to $3000 including necessary hardware and software.

No single study has simultaneously evaluated the validity and reliability of all accelerometers. Studies that have compared multiple units have focused on determining if there is a difference between uniaxial and multi-axial monitors. Most of these studies have reported strong positive correlations between types of monitors suggesting uniaxial and multi-axial accelerometers provide comparable information on physical activity. With lack of research comparing different types of accelerometers, at this point there is no definitive evidence suggesting one make or model of accelerometer is better than another and the choice is left to the best judgment of the researcher.

**Accelerometers in NHANES**

In NHANES, physical activity was monitored objectively using Actigraph AM-7164 accelerometers (Actigraph, Ft. Walton Beach, FL, USA). Actigraph AM-7164 accelerometers are uniaxial monitors used to measure vertical accelerations between 0.05 and 2.00 G in magnitude and at a frequency between 0.25 and 2.50 Hz. These
parameters reduce spurious data caused by vibrations from outside sources and restrict monitoring to normal human movement. The filtered movement is stored as an activity count for a user-specified ‘epoch’ interval. Epochs were set to one-minute to determine the participant’s minute-by-minute physical activity intensity.

Accelerometers were given out at the completion of the mobile exam center exam and were programmed to begin recording at 12:01 a.m. the following day. Monitors were worn for 7 consecutive days and attached with an elastic belt to the right hip. Thus, for each participant there were 10,080 epoch values (one for each minute of the week), with each of these values corresponding to their intensity of movement during that minute. Participants were asked to wear their accelerometer during all waking hours, except when it would get wet (e.g., water sports, showering/bathing).

The 10,080 epoch values were downloaded from the accelerometers by the Center for Disease Control and checked for biologically implausible data. Additional data reduction was completed by the candidate before analysis. Specifically, participants were only included in the analysis if they had complete monitoring data for at least 4 days, including at least one weekend day. Within adolescents, four days of physical activity monitoring using accelerometers has a test-re-test reliability correlation coefficient of 0.70. Days were considered complete if there was at least 10 hours of
monitoring time.\textsuperscript{8} Periods of 20 minutes or more of zero counts were assumed to indicate non-wear time and did not count towards the total wear time. An epoch threshold of $\geq 3000$ counts per minute was used to denote minutes of MVPA.\textsuperscript{9} This threshold is based on previous validation studies conducted in a similar age group and corresponds to a metabolic equivalent of 3 times that of resting, which equates to brisk walking.\textsuperscript{9} For each complete day of monitoring, data was filtered to determine the number of minutes spent engaged in: 1) bouts of MVPA ($\geq 5$ minutes), and 2) sporadic MVPA ($<5$ minutes). To calculate a bout of MVPA, we determined the number of minutes in which participants spent at least 80\% of the time above the threshold for MVPA (e.g., for a 10 minute bout, 8 minutes would have to be above 3000 counts/minute and this would count as 10 minutes). Furthermore, bouts had to be at least 5 minutes in duration. The 80\% threshold allowed us to account for the occasional rest period observed during bouts of physical activity (e.g., the short break between a goal in soccer and the re-start of the game). Sporadic physical activity was calculated as those minutes outside of bouts in which participants achieved the 3000 counts/minute threshold. Total MVPA for each day was then calculated as the sum of bouts and sporadic activity. Total minutes of MVPA were then averaged over the 4-7 day monitoring period to create a final variable for each participant that reflected their average MVPA in minutes per day.
Limitations of accelerometers

Although accelerometers have been proven to be a valid objective measure of physical activity in the pediatric population, they are not a perfect measure of physical activity and have associated limitations. In general, accelerometers are not waterproof and cannot be worn during water activities (e.g. swimming, water aerobics). Uniaxial accelerometers (such as those used in NHANES), measure vertical movements and are insensitive to activities that involve primarily upper torso movement (i.e., rowing) or movements with limited vertical displacement (i.e., cycling). Accelerometers also measure overall physical activity and are unable to discern different types of activities (e.g., soccer versus running).

Furthermore, accelerometers can only measure activity if they are actually worn by the participant, making compliance and important issue. Accelerometers were fitted to the individual participant, and an NHANES representative gave a brief overview of how to properly use the monitor during the mobile exam centre visit. Participants were also asked to maintain an activity diary to keep track of monitor wear time. Furthermore, NHANES provided participants with a toll-free telephone number and informational material describing the monitor and a pre-paid postage envelope along with $40 remuneration as an incentive to return the monitors after the 7-day period. A copy of the information given to participants is included in Appendix G.
Finally, the activity thresholds used in this analysis were based on previous research\textsuperscript{9} and best judgment of the authors. There are discrepancies in the literature as to what cut-points should be used to discern different levels of physical activity.\textsuperscript{9,10} It is possible that if different thresholds were used, the overall volume of objectively measured MVPA would have changed.
References


Appendix G

National Health and Nutrition Examination Survey: Informational Flyer
Informational Flyer
The Centers for Disease Control and Prevention (CDC) conducts the National Health and Nutrition Examination Survey (“NHANES”) to study the health of the U.S. population. As part of this study, a group of survey participants will wear physical activity monitors such as the one pictured here. The activity monitor records body movements during normal daily activities such as walking or jogging. The activity monitor records no other information.

Manufacturing Technology Incorporated of Fort Walton Beach, Florida manufactures the activity monitors. Over 5,000 of these monitors have been used in other studies. A 3-volt watch battery powers the monitors. The monitors are safe, durable, and comfortable to wear. The National Center for Health Statistics Institutional Review Board reviewed the survey procedures and a description of the equipment for safety. Survey participants will wear the activity monitors for 7 days during waking hours including activities such as school, camp, or work, whenever possible. The monitors are worn on a waist belt. The monitors are removed before going to bed or when the survey participant bathes, showers, or goes swimming.
If you have additional questions please call the NHANES Survey Toll-Free Information Line Number: 1-888-322-3024.
PHYSICAL ACTIVITY MONITOR INFORMATION SHEET

The last day you will wear the monitor is ____________________________________.

Mail back the monitor the next day using the padded envelope that was given to you.

This component studies the physical activity levels of children and adults.

What is an activity monitor?
An activity monitor is a small machine that records information about physical activity patterns. The monitor is safe. It uses a watch battery to power the monitor. The monitor records body movement during everyday activities such as walking. The monitor is safe to wear and will not cause discomfort while you wear it. Most people forget they are wearing it because it is lightweight and small enough to fit under clothing without being seen. Many studies with children and adults have used activity monitors. We hope to learn more about the activity levels of people who participate in NHANES.

What am I supposed to do with the activity monitor?
We ask that you wear the monitor every day for 7 days. Wear the monitor all day except when you shower, bathe, or go swimming. Your first full day wearing the monitor is tomorrow, however we would like you to start wearing the monitor when you get dressed before leaving here today. Please put the monitor on when you get up in the morning and take it off before you go to bed. Please keep the monitor away from small children and pets to avoid accidents. When the monitor is not being worn, put the monitor where children and pets cannot reach it.

How am I supposed to wear the activity monitor?
The monitor is worn on a belt. Attach the belt snugly around your waist so that the monitor rests on the right side of your body – close to your right hip. You will ideally wear the monitor under your clothes. It is best to keep the monitor fastened on the belt to reduce the chance of losing it. You will wear it at all times except when in the water, for instance, taking a bath or shower, or swimming. Please do not get the monitor wet. Water could damage the monitor. If you forget to take the monitor off before bathing or swimming, you will not be harmed.

What do I do after I have worn the monitor for 7 days?
Mail the monitor back at the end of the 7-day period. Place the monitor in the postage-paid padded envelope that you were given and drop the envelope in any United States Postal Service mailbox as soon as possible. Please do not return the belt. When we receive the monitor we will mail you a check for $40. If the monitor is not returned you will not be paid.

What if I get questions about the monitor?
Two copies of an information letter about the study are included. These are included in case you need to provide schools, camps, or work offices with information about the study. When passing through metal detectors at airports and work sites, it would be best to remove the monitor and put it in a separate bin for scanning. If questioned about the monitor, please show the information letter to security personnel.

Who do I contact if I have questions?
If you have questions about the monitor, please call our office toll-free at 1-888-322-3024.