

Physical Activity, Sedentary Behaviour, and Health in Children and Youth

by

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the degree Doctor of Philosophy

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ABSTRACT

There is currently a dearth of information suitable for the development of evidence-based physical activity and screen time guidelines for children and youth. The overarching purpose of this thesis was to generate findings that could be used to inform public health recommendations for physical activity and screen time. A series of six manuscripts were completed to explore the relationship between physical activity, sedentary behaviour, and health in youth.

The first manuscript examined the dose-response relation between objectively measured total and moderate-to-vigorous physical activity with blood pressure and hypertension. Participating in 30 and 60 minutes of moderate-to-vigorous physical activity per day decreased the odds of hypertension in youth by 50% and 63%, respectively.

The second manuscript explored the influence of intensity of physical activity and incidental movement on total and trunk adiposity. Moderate-to-vigorous intensity physical activity was found to predict total and trunk adiposity beyond other intensities and incidental movement.

The third manuscript sought to determine whether or not physical activity accrued in bouts was more beneficial than total physical activity with relation to being overweight. The inclusion of short and medium-to-long bouts of physical activity decreased the odds of overweight above and beyond total physical activity level.

The fourth manuscript included a detailed examination of the relation between physical activity and screen time by considering different forms of physical activity,

different physical activity environments, and various screen time behaviours. By and large, physical activity and screen time were not related.

The fifth manuscript determined the proportion of Canadian youth meeting screen time guidelines. Only 18% of girls and 14% of boys in grades 6 to 10 met screen time guidelines of no more than 2 hours per day.

The final manuscript examined the relationship between screen time and metabolic syndrome. A dose-response relation was observed between screen time and metabolic syndrome independent of physical activity level.

It is hoped that the findings from this thesis will provide useful information that will be considered in developing and modifying physical activity and screen time recommendations for the paediatric population.

CO-AUTHORSHIP

The manuscripts presented in this thesis are the work of Amy Mark in collaboration with her co-authors. Amy Mark was responsible for developing the research question, completing the data analysis, and writing the initial drafts of all 6 manuscripts. The co-authors of the manuscripts included in this thesis are Dr. Ian Janssen (manuscripts 1 thru 6) and Dr. William Boyce (manuscripts 4 and 5).

Manuscript 1: *Dose-Response Relation Between Physical Activity and Blood Pressure in Youth*. This manuscript is presented as it was published in *Medicine & Science in Sports & Exercise* 2008; 40(6):1007-1012. Dr. Janssen provided valuable input with regards to the design, statistical analyses, interpretation of results and editorial feedback on the manuscript. This research was funded by grants secured by Dr. Janssen.

Manuscript 2: *Influence of the Intensity of Movement and Physical Activity on Adiposity in Children and Youth*. This manuscript has been submitted to the *International Journal of Pediatric Obesity* and is presented according to the journal guidelines. Dr. Janssen provided valuable input with regards to the design, statistical analyses, interpretation of results and editorial feedback on the manuscript. This research was funded by grants secured by Dr. Janssen.

Manuscript 3: *Relation between sporadic and bouts of physical activity with overweight and obesity in youth*. This manuscript has been submitted with revisions to the *American Journal of Preventive Medicine* and is presented according to the journal guidelines. Dr. Janssen provided valuable input with regards to the design, statistical analyses, interpretation of results and editorial feedback on the manuscript. This research was funded by grants secured by Dr. Janssen.

Manuscript 4: *Relationship between Physical Activity and Screen Time*

Behaviours in Canadian Youth. This manuscript has not been published but has been presented according to the feedback from several journals. Dr. Janssen provided valuable input with regards to the design, statistical analyses, interpretation of results and editorial feedback on the manuscript. This research was funded by grants secured by Dr. Janssen. Dr. Boyce is the principal investigator for the *Health Behaviour in School-Aged Children* Survey in Canada and granted access to the data. Dr. Boyce also provided editorial feedback on the manuscript.

Manuscript 5: *Television Viewing, Computer Use, and Total Screen Time in*

Canadian Youth. This manuscript is presented as it was published in *Paediatrics and Child Health* 2006; 11(9):595-599. Dr. Janssen provided valuable input with regards to the design, statistical analyses, interpretation of results and editorial feedback on the manuscript. This research was funded by grants secured by Dr. Janssen. Dr. Boyce is the principal investigator for the *Health Behaviours in School-Aged Children* Survey in Canada and granted access to the data. Dr. Boyce also provided editorial feedback on the manuscript.

Manuscript 6: *Relationship Between Screen Time and Metabolic Syndrome in*

Adolescents. This manuscript is presented as it was published in the *Journal of Public Health* 2008; 30(2):153-160. Dr. Janssen provided valuable input with regards to the design, statistical analyses, interpretation of results and editorial feedback on the manuscript. This research was funded by grants secured by Dr. Janssen.

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CHAPTER 1

GENERAL INTRODUCTION

Children and youth are less active than in previous generations.¹ This is reflected by the increased prevalence of childhood obesity, which has reached epidemic proportions in Canada² and most other industrialized countries.³ The inverse relation between physical activity with obesity and cardiometabolic risk factors in children and youth is well established.³⁻⁹ Conversely, a positive relation between obesity and sedentary behaviours such as television viewing has also been consistently reported.¹⁰⁻¹⁴

Given the well established relations between physical activity, sedentary behaviours, and health in the paediatric population, several countries and organizations have developed public health guidelines for physical activity¹⁵⁻¹⁷ and screen time (combined television, computer and video game use)^{18, 19} for this age group.

Unfortunately, some of the specific recommendations made within the physical activity and screen time guidelines are not based on strong evidence and several important and unanswered questions remain. What is the minimal/maximal and optimal volume of physical activity and screen time? What intensity should physical activity be performed at? Can physical activity be accumulated in a sporadic manner (e.g., one minute here and there over the course of the day), or is it preferable to accumulated physical activity in bouts (e.g., a few 10-15 minute sessions)? Are physical inactivity and excessive screen time synonymous behaviours, or are these separate behaviours that should be targeted as such in the guidelines?

Overview and Purpose of the Thesis

The overarching theme of this research was to better decipher the relation between physical activity, screen time, and health in youth by addressing the questions noted above. The overall goal was to generate evidence that could be used to better inform child and youth public health guidelines for physical activity and screen time. The thesis is presented in manuscript format, and each of the six manuscripts addresses a specific component of the current physical activity and/or screen time guidelines.

Manuscript 1 focuses on the volume component of the physical activity guidelines and examines the dose-response relation between physical activity and blood pressure (hypertension) in youth.

Manuscript 2 focuses on the intensity component of the physical activity guidelines. The purpose of this manuscript was to examine the influence of the intensity of movement, during both active and sedentary time, on total and abdominal adiposity.

Manuscript 3 explores whether physical activity guidelines for youth should consider whether physical activity needs to be accumulated in bouts. Specifically, this manuscript examined whether physical activity accrued in bouts was a better predictor of adiposity than physical activity accrued in a sporadic manner (e.g., a couple of minutes here and there throughout the day).

Manuscript 4 examines the relation between physical activity and screen time. The specific purpose of this manuscript was to determine whether guidelines and active living interventions should target one or both behaviours to ensure that youth meet both physical activity and screen time recommendations.

Manuscript 5 sought to determine the proportion of Canadian youth attaining screen time guidelines. Discerning the number of youth achieving screen time recommendation provides evidence about whether or not guidelines are realistic, and also supplies information regarding the scope of the problem in youth.

Manuscript 6 focuses on the volume aspect of screen time. This manuscript explored whether spending more than the recommended 2 hours per day in front of screens (television, computer, video games) was associated with an increased odds of the metabolic syndrome. The metabolic syndrome represents a clustering of cardiovascular and metabolic risk factors that substantially increases the risk of developing type 2 diabetes and cardiovascular disease.^{20, 21}

These manuscripts are followed by a general discussion which identifies the key findings from each manuscript, the strengths and limitations of the thesis, and discusses the public health implications of this research. A list of the abbreviations used in the various manuscripts is provided in Appendix A.

References

1. Krebs NF, Jacobson MS. Prevention of pediatric overweight and obesity. *Pediatrics* 2003;112(2):424-30.
2. Shields M. Overweight and obesity among children and youth. *Health Rep* 2006;17(3):27-42.
3. Janssen I, Katzmarzyk PT, Boyce WF, et al. Comparison of overweight and obesity prevalence in school-aged youth from 34 countries and their relationships with physical activity and dietary patterns. *Obes Rev* 2005;6(2):123-32.
4. Ness AR, Leary SD, Mattocks C, et al. Objectively measured physical activity and fat mass in a large cohort of children. *Plos Medicine* 2007;4(3):476-84.
5. Andersen LB, Harro M, Sardinha LB, et al. Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study). *Lancet* 2006;368(9532):299-304.
6. Wareham NJ, van Sluijs EM, Ekelund U. Physical activity and obesity prevention: a review of the current evidence. *Proc Nutr Soc* 2005;64(2):229-47.
7. Dencker M, Thorsson O, Karlsson MK, et al. Daily physical activity related to body fat in children aged 8-11 years. *J Pediatr* 2006;149(1):38-42.
8. Molnar D, Livingstone B. Physical activity in relation to overweight and obesity in children and adolescents. *Eur J Pediatr* 2000;159 Suppl 1:S45-55.
9. Dowda M, Ainsworth BE, Addy CL, Saunders R, Riner W. Environmental influences, physical activity, and weight status in 8- to 16-year-olds. *Arch Pediatr Adolesc Med* 2001;155(6):711-7.

10. Dietz WH, Jr., Gortmaker SL. Do we fatten our children at the television set? Obesity and television viewing in children and adolescents. *Pediatrics* 1985;75(5):807-12.
11. Janssen I, Katzmarzyk PT, Boyce WF, King MA, Pickett W. Overweight and obesity in Canadian adolescents and their associations with dietary habits and physical activity patterns. *J Adolesc Health* 2004;35(5):360-7.
12. Andersen RE, Crespo CJ, Bartlett SJ, Cheskin LJ, Pratt M. Relationship of physical activity and television watching with body weight and level of fatness among children: results from the Third National Health and Nutrition Examination Survey. *JAMA* 1998;279(12):938-42.
13. Crespo CJ, Smit E, Troiano RP, Bartlett SJ, Macera CA, Andersen RE. Television watching, energy intake, and obesity in US children: results from the third National Health and Nutrition Examination Survey, 1988-1994. *Arch Pediatr Adolesc Med* 2001;155(3):360-5.
14. Tremblay MS, Willms JD. Is the Canadian childhood obesity epidemic related to physical inactivity? *Int J Obes Relat Metab Disord* 2003;27(9):1100-5.
15. Strong WB, Malina RM, Blimkie CJ, et al. Evidence based physical activity for school-age youth. *J Pediatr* 2005;146(6):732-7.
16. Health Canada and Canadian Society for Exercise Physiology. Canada's Physical Activity Guide to Healthy Active Living: Family Guide to Physical Activity for Youth 6-9 Years of Age. In. Ottawa, ON: Minister of Health; 2002.

17. Health Canada and the Canadian Society for Exercise Physiology. Canada's Physical Activity Guide to Healthy Active Living: Family Guide to Physical Activity for Youth 10-14 Years of Age. In. Ottawa, ON: Minister of Health; 2002.
18. American Academy of Pediatrics: Children, adolescents, and television. *Pediatrics* 2001;107(2):423-6.
19. Impact of media use on children and youth. *Paediatrics & Child Health* 2003;8(5):301-6.
20. Ardern CI, Janssen I. Metabolic syndrome and its association with morbidity and mortality. *Appl Physiol Nutr Metab* 2007;32(1):33-45.
21. Ford ES. Risks for all-cause mortality, cardiovascular disease, and diabetes associated with the metabolic syndrome: a summary of the evidence. *Diabetes Care* 2005;28(7):1769-78.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

There is substantial evidence supporting the association between physical inactivity and screen time (combined television, computer and video game use) with negative health outcomes in children and youth.¹⁻¹⁴ Establishing healthy physical activity and screen time behaviours during childhood and adolescence is important for current as well as future health as both behaviours have been shown to track into adulthood.^{15, 16} Furthermore, the origins of many chronic diseases are believed to be in childhood.¹⁷ Physical activity and screen time guidelines are needed to educate individuals about the desirable amount of each of the behaviours.

2.2 Background

2.2.1 Key Definitions

2.2.1.1 Physical Activity

Physical activity refers to “any bodily movement produced by skeletal muscles that results in energy expenditure”¹⁸ and includes four components: volume, intensity, frequency, and type. All four components of physical activity can contribute to health. However, guidelines generally focus on the volume, frequency, and intensity of physical activity. The volume component specifies the minimum number of minutes individuals should engage in physical activity each day. The Canadian Physical Activity guidelines specify that these minutes should be accrued in bouts^{19, 20} whereas other guidelines

simply recommend the accumulation of physical activity throughout the day.²¹⁻²⁴

Frequency refers to the number of times per day or week that an individual should participate in physical activity. Recent physical activity guidelines for children and youth recommend daily participation in physical activity.^{19, 20, 22}

Intensity can be thought of as the degree of exertion, sometimes expressed relative to resting energy expenditure as metabolic equivalents (METs; 1 MET equals the energy expended at rest). Typically, recommendations will refer to low (1.5-3 METs), moderate (3-6 METs), vigorous (≥ 6 METs), and/or moderate-to-vigorous (combined moderate and vigorous) intensities of physical activity.

The final component of physical activity relates to the types of activities in which individuals should engage. Physical activity recommendations for children and youth advocate the inclusion of several types of activity including endurance, strength, and flexibility activities.

2.2.1.2 Screen Time and Sedentary Behaviours

Sedentary behaviours are activities where energy expenditure remains close to resting levels and includes activities such as reading, watching television, listening to music, and talking on the phone. In population based research screen time is the most common measure of sedentary behaviour and includes time spent watching television and/or videos, playing computer and/or video games, and using the computer for activities such as surfing the internet and chatting. Focus has likely been placed on screen time because it is relatively simple to measure and because it has been linked to negative health outcomes such as obesity, violent and aggressive behaviour, and early initiation of sexual behaviours.²⁵ Recently, attention has also been given to activity level

during sedentary time, referred to as incidental movement.²⁶ Incidental movement is defined as movement outside of structured physical activity, including short bursts of light intensity physical activity such as walking up and down stairs, moving around the house, and fidgeting.

2.2.1.3 Health

The World Health Organization defines health as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity”.²⁷ This thesis focuses on physical health measures related to cardiometabolic health.

Specifically, cardiometabolic health refers to diabetes and cardiovascular disease outcomes. Cardiometabolic risk factors, therefore, refer to risk factors for these diseases and include impaired fasting glucose, insulin resistance/metabolic syndrome, high blood pressure, obesity, and dyslipidemia (e.g., high blood cholesterol). For the purpose of this thesis, the term ‘health’ refers to having cardiometabolic risk factor values (e.g., blood pressure) within the normal range. Focus has been placed on cardiometabolic risk factors because of their public health burden. In Canada, heart disease and diabetes accounted for 126.8 and 19.6 deaths per 100,000 people in 2004, respectively.²⁸ Cardiovascular disease remains the leading cause of death in Canada.²⁸

2.2.1.4 Children and Youth

Children includes those between infancy and puberty (aged 2 to 10 years). Youth refers to the adolescent period between puberty and full growth, and represents persons aged 11 to 19 years. This thesis focuses on school-aged children and youth within the age range of 8 to 19 years.

2.2.2 Physical Inactivity in Canadian Children and Youth

In 2008, for the second year in a row, Canadian youth received an “F” grade on the physical activity participation component of the Active Healthy Kids Canada Report Card.²⁹ This grade was based on the results from several surveys. First, the 2005 Canadian Community Health Survey (CCHS), an interview based study completed in a representative sample of Canadians, indicates that only 50.9% (58% of male and 44% of female) of youth aged 12 to 19 years are physically active.³⁰ Within the CCHS the average daily energy expenditure was derived from multiplying the frequency and duration of each activity by the energy cost of the activity (in kilocalories per kilogram of body weight per hour).³⁰ The daily energy expenditure of each activity was then summed to determine total energy expenditure. A threshold of ≥ 3 kilocalories per kilogram of body weight per day, equivalent to walking for about one hour or jogging for 20 minutes, was used to denote those who were physically active.³⁰ This threshold falls far below any of the recommendations for physical activity in youth, and the physical inactivity prevalence of 49.1% based on the CCHS should be considered as a conservative estimate. The activity level of younger Canadians, aged 6 to 11 years, was assessed during the 2004 CCHS by parental report. Parents reported on how many hours per day their child was active during the previous 7 days. A total 83.0% of youth participated in 1 hour/day, while 42.1% and 9.7% participated in 2 hours/day and 3 hours/day, respectively.³¹

The physical activity level of Canadian youth aged 11 to 15 years was also evaluated as part of the World Health Organization’s 2005/2006 *Health Behaviour in School-Aged Children* (HBSC) survey,³² a classroom based questionnaire administered in 40 countries (see Appendix C for a detailed description of the survey methodology).

Youth were classified as physically active if they met the 60 minutes of physical activity per day recommended by the World Health Organization,²¹ the Evidence Based Guidelines,²² and others.^{24, 33-35} The majority of Canadian youth were found to be inactive with only 26%, 16%, and 13% of females aged 11, 13, and 15 years of age, respectively, reporting 60 or more minutes of daily physical activity.³² The corresponding values in males were 36%, 31%, and 27%.

More recently, the physical activity level of Canadian youth was measured objectively using pedometers over 7 days as part of the *Canadian Physical Activity Levels Among Youth* study. On average, school-aged children and youth took 11,500 steps per day. Only ~10% of youth took more than 16,500 steps per day, which is equivalent to the 90 minutes of physical activity recommended in the Canadian Physical Activity Guidelines.³⁶ These new physical inactivity statistics, which for the first time provide objective measures of physical activity levels of Canadians at the population level, are particularly concerning and suggest that the child and youth physical inactivity crisis is far worse than originally believed based on subjective (e.g., questionnaire based) measures of physical activity.

2.2.3 Excessive Screen Time in Canadian Children and Youth

Since the development of the screen time guidelines, very few studies have sought to determine the number of children and youth achieving the recommended 2 hours or less per day. Only ~12% of Australian adolescents were found to meet this guideline.³⁷ In the United States 45% of youth aged 8 to 16 years watch more than 2 hours of television a day¹¹ while around a quarter of males and just less than a fifth of females watching four or more hours of screen time per day.⁸

Only in the past three years has information regarding the prevalence of excessive screen time in Canadian youth been available. As with physical activity participation, Canadian youth received an “F” grade on screen time in the 2008 Active Healthy Kids Canada Report Card.²⁹ Recent estimates for the proportion of Canadian youth meeting screen time guidelines range from 11% from the 2005/2006 Health Behaviour in School-Aged Children survey (11-15 year olds) to 44% from the New Brunswick Student Wellness Survey (11-17 year olds).²⁹ Although screen time is higher on weekends compared to weekdays, it is still too high during the week.²⁹ Males tend to have higher screen time levels than females, which is primarily attributable to higher video game use.²⁹

2.3 Overview of the Relation Between Physical Activity, Sedentary Behaviours, and Health

The relation between physical activity and health in school-age children and youth is provided from cross-sectional,^{1, 2, 4, 14, 38-40} longitudinal,^{16, 41-43} and intervention⁴⁴⁻⁴⁸ based research, a sample of which are referenced here. The positive influence of physical activity is substantiated by the multitude of health outcomes this behaviour is related to, which include but is not limited to, obesity,^{2, 4, 38, 41} insulin resistance,^{14, 39} triglycerides,¹ cholesterol,¹ and a clustered cardiometabolic risk score.^{1, 40} The relationship between physical activity and health in young people with physical activity and health in adulthood is illustrated in Figure 1 (next page). Physical activity during childhood has important immediate, as evidenced above, and long term health benefits given that cardiovascular disease starts in childhood.⁴⁹ Cardiometabolic risk factors such

as hypertension⁵⁰ and the metabolic syndrome^{51, 52} have been shown to track from adolescence into adulthood. As well, physical activity levels have been shown to track, albeit modestly, from childhood and adolescence into adulthood^{16, 53} where similar relations between physical activity and cardiometabolic health have been observed.⁵⁴⁻⁵⁶

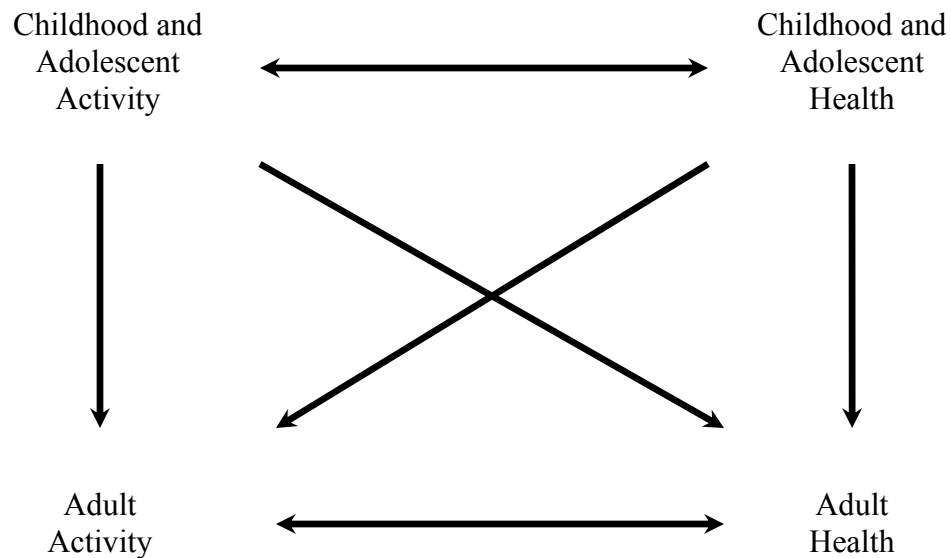


Figure 1: Relation between childhood and adolescent activity and health, with adult activity and health. Taken from RM Malina, 2001.¹⁵

The negative influence of physical inactivity on health is also apparent from studies examining the relation between sedentary behaviour and health. Within the literature, especially in population based research, screen time is the most common measure of sedentary behaviour. Findings from cross-sectional,^{57, 58} longitudinal,⁵⁹ and intervention^{44, 60} studies all provide evidence of a relation between screen time and health. Health outcomes that are known to be related to screen time levels in children

and youth include violent and aggressive behaviours, body self-image issues, substance use and abuse,²⁵ and obesity.^{44, 57-60} However, the relation between screen time and measures of physical health outcomes outside of obesity has not been thoroughly examined. Television viewing during childhood and adolescence has also been found to correlate with adult levels of television viewing,⁵⁹ implying that this negative health behaviour tracks over time.

There has been a recent interest in determining whether activity level during sedentary time, referred to as incidental movement, influences health. Although a new area of research, with limited scientific evidence (as will be reviewed in section 2.5.6), the possible influence of a lack of incidental movement on health within our current obeseogenic environment is an intriguing one, and something that should be considered when making physical activity recommendations.

2.4 Physical Activity and Screen Time Guidelines

The relations between physical activity and screen time with health emphasize the need to provide public health guidelines and recommendations to ensure that children and youth engage in an appropriate amount of each behaviour to benefit their immediate and long-term health. The next sections of this review will consider the existing physical activity and screen time guidelines, and the process and evidence that was used to inform the development of these guidelines.

2.4.1 Process for Developing Guidelines

In general, the process for developing a set of physical activity or screen time guidelines begins with the assembly of an expert panel. It is the expert panel's job to

evaluate and weigh the scientific evidence linking physical activity and/or screen time with health, and to translate this evidence into recommendations for the child and youth population. Ideally, the evaluation is completed using a systematic review process; however, in reality the evaluation has typically been performed using a less scientifically rigorous narrative review of the relevant literature. Based on the relations observed in the literature, guidelines and recommendations are made by the expert panel regarding the behaviour of interest. For example, the expert panel may make recommendations about the specific volume of physical activity in which youth should participate based on the published evidence of the dose-response relation between physical activity with risk factors and health outcomes. When there is insufficient evidence to inform some or all aspects of the guidelines, the expert panel will make a “best guess” based on the limited literature that is available, experiences from their own research, and their expert opinion. As advances are made in the literature that informs the guidelines and their recommendations, there is a corresponding need for the guidelines to be updated by the expert panel on a periodic basis.⁶¹

When guidelines are being developed factors such as population and individual level health promotion, the prevalence of the undesirable behaviour within the population, and the population attributable risk of morbidity and mortality attributable to the undesirable behaviour are also considered.⁶¹ Finally, the evidence is translated into specific guidelines by: 1) developing messages that are based on psychological theory, 2) concentrating on practical information from the evidence, and in the case of children and youth, 3) providing behaviour change principles to individuals (e.g. parents) who have

influence over the population group for whom the guidelines are developed (e.g. children).⁶¹

2.4.2 Physical Activity Guidelines

A summary of existing physical activity guidelines for school-aged children and youth, along with the key recommendations from each guideline, are presented in Table 1 (see next page). The first set of physical activity recommendations for youth were published in 1988 by the American College of Sports Medicine.⁶² The recommendation, based on the available literature in adults at that time and a limited amount of published information on the pediatric population, was for children and youth to participate in at least 20 to 30 minutes of vigorous exercise on a daily basis⁶² (Table 1). This was followed in 1994 by a Consensus Statement that was developed in the International Consensus Conference on Physical Activity Guidelines for Adolescents (Table 1). The expert panel recommended that adolescents, which they defined as 11 to 21 year olds, should be physically active on a daily basis and that they should participate in at least three 20 minute sessions per week at a moderate-to-vigorous intensity.⁶³ In 1995, an expert panel assembled by the National Institutes of Health made the recommendation for children to participate in moderate-to-vigorous intensity physical activity for 30 minutes on most, but preferably all, days of the week⁶⁴ (Table 1).

In 1998 the physical activity recommendations changed dramatically, reflecting an increased amount research on the relation between physical activity and health in children and youth. The recommendation by the UK Health Education Authority was for children and youth to accumulate 60 minutes of moderate-to-vigorous intensity physical activity on a daily basis²³ (Table 1). Since 1998 several other countries and organizations

Table 1 Physical activity guidelines for youth.

Organization	Title of Recommendation	Year	Age Range	Recommendation
American College of Sports Medicine ⁶²	Opinion statement on physical fitness in children and youth	1988	Children and youth	Obtain 20 to 30 minutes of vigorous exercise daily
International Consensus Conference on Physical Activity Guidelines for Adolescents ⁶³	Physical activity guidelines for adolescents: consensus statement	1994	11 – 21 y	Be physically active daily, or nearly daily, as part of play, games, sports, work, transportation, recreation, physical education, or planned exercise, engage in ≥ 3 sessions/week of moderate-to-vigorous activities that last ≥ 20 min
US National Institutes of Health ⁶⁴	Consensus development panel on physical activity and cardiovascular health	1995	All	Accumulate 30 min of moderate physical activity on most, preferably all, days of the week
US Surgeon General ⁶⁵	Physical activity and health	1996	≥ 2 y	Accumulate 30 min of moderate physical activity on most, preferably all, days of the week
UK Health Education Authority ²³	Young people and health-enhancing physical activity: evidence and implications	1998	Children and youth	Participate in physical activity that is of at least moderate intensity for an average of 1 h/d; participate in physical activities that enhance and maintain strength in the musculature of the trunk and upper arm girdle ≥ 2 d/week; the above recommendation should be met by participating in developmentally appropriate activities
Australia Department of Health and Ageing ²⁴	National physical activity guidelines for Australians	1999	5 – 18 y	At least 60 min, and up to several hours, of moderate-to-vigorous physical activity every day; limit screen time ≤ 2 h/d
American Cancer Society ³⁴	Guidelines on nutrition and physical activity for cancer prevention	2002	Children and youth	Engage in ≥ 60 min/d of moderate-to-vigorous physical activity at least 5 d/week

Table 1 (*continued*)

Organization	Title of Recommendation	Year	Age Range	Recommendation
Health Canada and the Canadian Society for Exercise Physiology ^{19, 20}	Canada's physical activity guide for children and youth	2002	6 – 14 y	Increase time currently engaged in physical activity by at least 30 min/d (in periods of at least 5 – 10 min), progressing to ≥ 90 min/d more physical activity; the 90 min/d increase in physical activity should include both moderate (60 min) and vigorous (30 min) activities; decrease time spent doing sedentary activities (television, video games, internet), initially by 30 min/d, eventually by ≥ 90 min/d
Weight Realities Division of the Society for Nutrition Education ⁶⁶	Guidelines for childhood obesity prevention program	2003	Children	Be active for at least 60 min/d; limit screen time to < 2 h/d and replace with more active activities
US National Association for Sports and Physical Education ³⁵	Guidelines for appropriate physical activity for elementary school children	2003	5 – 12 y	Accumulate at least 60 min, and up to several hours, of age-appropriate physical activity on all, or most days of the week; daily accumulation should include moderate and vigorous physical activities, with the majority being intermittent in nature
US Department of Agriculture ⁶⁷	Dietary guidelines for Americans	2005	Children and youth	Accumulate ≥ 60 min of physical activity on most, preferably all, days of the week.
Divisions of nutrition and physical activity and adolescent and school health of the US Center for Disease Control ²²	Evidence based physical activity for school-age youth	2005	6 – 18 y	Participate in ≥ 60 min/d of moderate-to-vigorous physical activity; activities should be developmentally appropriate, enjoyable, and include a variety of activities

have made similar recommendations for 60 minutes of daily activity including the American Cancer Society,³⁴ the U.S. Department of Agriculture,³³ the U.S. National Association for Sports and Physical Education,³⁵ the Australian Department of Health and Ageing,²⁴ and the Weight Realities Division of the Society for Nutrition Education⁶⁶ (Table 1). The only exception appears to be the Canadian Physical Activity Guidelines for Children and Youth, which were released in 2002, that recommend that children (aged 6-9 years) and youth (aged 10-14 years) should *increase* their current physical activity level by 90 minutes per day^{19,20} (Table 1). A review of the Canadian Physical Activity Guidelines for children and youth completed in 2007 clearly indicates the need for the guidelines to be revised according to current evidence.⁶⁸

In 2005 an expert panel, sponsored by the U.S. Centers for Disease Control and Prevention, completed the first systematic review examining the relation between physical activity and several physiological and psycho-social health outcomes in school-aged children²² (Table 1). Their resultant recommendation is in agreement with the previous recommendation that school-aged children and youth should accumulate at least 60 minutes of moderate-to-vigorous intensity physical activity on a daily basis.²² Although over 300 articles were included in the systematic review, the expert panel raised concerns over the lack of strong evidence for the volume of physical activity required for health and well-being in children and youth.²² In agreement with this statement, a comprehensive review of literature completed in 2007 as part of the Canadian physical activity guidelines project also indicated that the dose-response relation between physical activity and health in children and youth remains unclear.⁶⁸

Aside from the specific volume or dose of physical activity that should be performed by children and youth, questions remain as to how the physical activity should be accumulated. Specifically, should some or all of the physical activity performed should be accumulated in bouts (e.g., at least 10 minutes long) or can it be entirely sporadic (e.g., a couple of minutes here and there) in nature? Furthermore, if bouts of physical activity are preferred, what is the preferred length of the bout? Canada's Physical Activity Guide recommends that children and youth accumulate physical activity in 5-10 minute bouts^{19, 20} however, similar recommendations have not been made by other countries and organizations.²² The evidence informing this recommendation will be discussed in the section reviewing the literature in the area of physical activity and health (section 2.5.2).

A similar dearth of information exists regarding the intensity of physical activity that is most beneficial for a child's health, as will be discussed further in the section reviewing the literature in the area of physical activity and health (section 2.5.3). The majority of the current physical activity guidelines recommend participation in moderate-to-vigorous intensity physical activity.²² In contrast, the Canadian guidelines recommend increasing moderate intensity physical activity by 60 minutes and vigorous intensity physical activity by 30 minutes per day^{19, 20} (Table 1).

A unique component of the Canadian and Australian physical activity guidelines that warrants mentioning is the inclusion of a screen time component. The Canadian guidelines recommend *decreasing* screen time by 90 minutes per day^{19, 20} while the Australian Guidelines recommend limiting screen time to <2 hr/d²⁴ (Table 1). Controversy exists in the literature about the separate targeting of physical activity and

sedentary behaviours. The displacement theory contends that increases in screen time in recent decades has replaced time that would have been spent in physical activity in previous years, suggesting that only one behaviour needs to be targeted for improvements to be seen in both (e.g., decreasing screen time will result in an increase in physical activity). There is discrepancy in the literature concerning this relation which will be discussed further in the section reviewing the literature examining the relation between physical activity and sedentary behaviour (section 2.5.4).

2.4.3 Screen Time Guidelines

An overview of the available screen time guidelines for youth are presented in Table 2 (see next page). Screen time has been used as a proxy measure of sedentary behaviour, and includes time spent watching television, using the computer, and playing video games. There is increasing evidence linking high screen time to health consequences such as obesity, violent and aggressive acts, initiation of early sexual behaviours, body self-image issues, and substance use and abuse in children and adolescents.^{8, 10-12, 25, 69} The negative impact of excessive screen time on the health and well-being of children and youth prompted the Canadian Paediatric Society and the American Academy of Pediatrics to establish public health and clinical guidelines for screen time use. Both the Canadian Paediatric Society⁷⁰ and the American Academy of Pediatrics⁷¹ recommend limiting screen time to no more than 2 hours per day (Table 2). Although the American and Canadian guidelines are in agreement, it is not clear how the two hour per day threshold was established. The evidence informing the screen time recommendation will be discussed in the section reviewing the literature in the area of screen time and health (section 2.5.5).

Table 2 Screen time guidelines.

Organization	Title of Recommendation	Year	Age Range	Recommendation
American Academy of Pediatrics ⁷¹	Children, adolescents, and television	2001	Children and adolescents	Limit children's total media time to no more than 1 to 2 hours of quality programming per day
Canadian Paediatric Society ⁷⁰	Impact of media use on children and youth	2002	Children	Television watching should be limited to no more than 1h to 2 h per day

2.5 Evidence Informing Physical Activity and Screen Time Guidelines

2.5.1 Volume of Physical Activity and Health

The volume or dose of physical activity recommended within the different physical activity guidelines that are outlined in Table 1 are somewhat inconsistent. The Canadian Physical Activity Guidelines^{19, 20} recommend increasing physical activity by 90 minutes per day, while the other guidelines published within the past 10 years generally recommend 60 or more minutes of moderate-to-vigorous physical activity on a daily basis. The following section will review the literature that has examined the dose-response relation between physical activity and health within school-aged children and youth. The results from intervention and observational studies examining the relation between physical activity and various cardiometabolic health outcomes will be examined.

2.5.1.1 Obesity

Obesity has reached epidemic proportion in youth.⁷² Accordingly, numerous studies have examined the physical activity-obesity relation. A systematic review of obesity treatment interventions (n= 14 studies) suggests that only 155 to 180 minutes of moderate-to-vigorous physical activity per week (~22 to 26 minutes/day) is effective at

reducing body fat within overweight and obese youth.⁴⁵ This volume of physical activity is much lower than that recommended in recent physical activity guidelines (Table 1). However, the dose of physical activity presented in these studies only included the volume of physical activity that was part of the interventions and did not include any time youth spent being physically active outside of the intervention situation (e.g., playing at recess, physical education class, team sports). Thus, the appropriate volume of physical activity for obesity treatment remains unclear. Furthermore, the studies included in this systematic review were limited to overweight and obese participants, thereby limiting the generalizability of these findings for the use in physical activity recommendations. Unfortunately, overweight and obesity prevention interventions that are capable of addressing the dose-response relation between physical activity and adiposity are unrealistic. This type of intervention would require extensive financial and human resources and would place an unrealistic burden on the research participants as obesity develops slowly over several years in most circumstances.

Longitudinal studies examining the physical activity-obesity relation may provide some insight into the volume of physical activity required for obesity prevention. Several longitudinal studies found no relation between physical activity and adiposity,^{42, 73-75} although this may be a reflection of the poor measures of physical activity (e.g., self-report) that were used in these studies. A recent study, which employed objective measures of physical activity, followed youth from 4 to 11 years of age.⁴¹ Within this study participants in the highest tertile of physical activity over the 8 years had a lower body mass index.⁴¹ Unfortunately, no information was provided on the amount of physical activity in which the youth in the highest tertile participated.

Cross-sectional studies offer further, albeit weaker, form of evidence regarding the appropriate volume of physical activity for obesity prevention. Findings from the Avon Longitudinal Study of Parents and Children indicate that adiposity, measured by standard deviation scores of fat mass, was 0.25 units lower in 11 year old males and 0.15 units lower in 11 year old females for each 15 minute/day increase in the volume of moderate-to-vigorous physical activity.² As well, the odds of being overweight decrease in an inverse dose-response fashion by quintile of moderate-to-vigorous physical activity. The odds of obesity was less than 0.50 for males in the second physical activity quintile (ranging between 14.14 and 21.50 min/d of physical activity) and females in the fifth physical activity quintile (ranging between 27.29 and 77.14 min/d of physical activity).²

Overall, results from those studies examining the relation between physical activity and adiposity suggest that as little as 30 minutes of daily physical activity is beneficial. However, due to the lack of studies that have systematically explored the dose-response relation, further research is clearly required.

2.5.1.2 Blood Lipids and Lipoproteins

Physical activity has been found to have mixed effects on blood lipids and lipoprotein levels in youth. A meta-analysis of interventions found that short-term training studies had little influence on total cholesterol, high density lipoprotein cholesterol, or low density lipoprotein cholesterol, with a trend towards significance for triglyceride.⁷⁶ Interventions lasted between 5 and 16 weeks, with physical activity doses ranging between 20 and 60 minute sessions at a frequency of 3 to 5 times per week (total dose of interventions ranged between 480 – 2560 minutes/week).⁷⁶ Significant improvements in triglycerides and a trend for increased high density lipoprotein

cholesterol was only observed in those studies that were limited to overweight and obese participants.⁷⁶ Unfortunately, the results from these studies do not provide any insight into the volume of physical activity required to reduce the likelihood of having high low density lipoprotein cholesterol, high total cholesterol, high triglycerides, or low high density lipoprotein cholesterol.

Similarly, a 12 week intervention completed in a small sample (n=36) of 10- to 12-year-olds found no significant dose-response relation between physical activity and blood lipids/lipoprotein.⁷⁷ Participants engaged in either low (~60 minutes per week) or moderate (~78 minutes per week) volume exercise programmes. Given the small (~18 minutes per week) differences in duration of physical activity across groups, the researchers, not surprisingly, failed to find dose-response or threshold effects on blood cholesterol and lipids. It is important to note that even their moderate volume exercise program (~78 minutes per week) would be considered insufficient by all physical activity guidelines.

Observational studies report relations between physical activity and blood lipids and lipoproteins^{1, 13, 78, 79} however, these studies have not examined the dose-response nature of the relations.

2.5.1.3 Blood Pressure

A meta-analysis of 25 intervention studies did not observe a dose-response relation between physical activity and blood pressure.⁸⁰ Interventions lasted between 4 and 40 weeks with participants engaging in physical activity between 2 and 5 days per week for 10 to 75 minutes per session (the total dose of interventions ranged between 560 and 5250 minutes).⁸⁰ In contrast, a dose-response relation has been observed in cross-

sectional studies. One study found that for every 100 metabolic- equivalent hour increase in physical activity, systolic blood pressure decreased in a linear manner by 1.15 mmHg.⁸¹ Unfortunately, the physical activity measurement unit employed in this cross-sectional study does not provide information that can be transformed into an understandable public health message (e.g., minutes of physical activity per day). Another study found that for every 15 minute increase in moderate-to-vigorous intensity physical activity, systolic blood pressure decreased by ~0.5 mmHg.⁸² To put these findings into perspective, to change systolic blood pressure by a modest 5 mmHg, youth would need to participate in 2.5 hours of moderate-to-vigorous physical activity.

Taken together, these results suggest that far greater volumes of physical activity than the recommended 60 minutes per day may be required to influence blood pressure. It is noteworthy that the studies to date have tended to focus on mean blood pressure values. Examining the influence of physical activity on those with hypertension and or predicting blood pressure values within the ‘at risk’ range may yield different results. Studies in adults suggest that physical activity has a limited influence on cardiometabolic risk factor values that fall within the normal healthy range.⁸³

2.5.1.4 Metabolic Syndrome

To my knowledge, only a single study has examined the dose-response relation between physical activity and clustered cardiometabolic risk factors, often referred to as the metabolic syndrome. This was a cross-sectional study, which employed objective measure of physical activity (accelerometers) and examined a large sample (n = 1732) of 9- and 15-year olds from 3 countries.¹ An inverse dose-response relation was observed between physical activity quintile and clustered cardiometabolic risk factors whereby

greater benefits were seen with increased physical activity.¹ The authors suggest that youth may need to participate in 88-116 minutes of physical activity per day (representing those in the fourth physical activity quintile) in order to decrease the likelihood of having clustered cardiometabolic risk factors,¹ much higher than the recommended 60 minutes per day. However, the threshold used to define physical activity was lower than the recommended cut-off point for moderate-to-vigorous, therefore, some low intensity physical activity was included in the measure. These results need to be confirmed prior to recommending that youth participate in such a high volume of physical activity.

2.5.1.5 Summary

Although intervention studies provide the strongest type of evidence of a cause and effect relationship, the results from this type of study have provided limited information on the dose-response relation between physical activity and health. This may reflect the fact that it is not practical or feasible to study a variety of possible “doses” to determine the ideal volume of physical activity required for the treatment and/or prevention of poor health. Findings from longitudinal observational studies permit the temporal sequence between physical activity and its associated health outcomes to be established. However, only a handful of longitudinal studies provide information about the dose of physical activity related to health^{41, 73} with many studies reporting no relation.^{42, 73-75} The results from longitudinal studies are also difficult to interpret because of the subjective measures of physical activity (e.g., self-report) employed in these studies. Self-report physical activity only modestly correlates with objective measures,

and there is a tendency for self-reported physical activity over estimate actual physical activity level.⁸⁴

The most convincing evidence of a dose-response relation between physical activity and cardiometabolic health in the pediatric population comes from cross-sectional studies. Evidence from these studies reveals an inverse relation between physical activity with adiposity,^{2, 4, 10, 38, 47, 58, 85} blood pressure,^{81, 82} and a clustered cardiometabolic risk factor score.¹ Unfortunately, several of these studies relied on self-report measures, the implications of which were discussed in the preceeding paragraph. Others have used categories of physical activity (e.g., quartiles and quintiles) with wide ranges in activity.^{2, 4, 85} To best explore the dose-response relation between physical activity and health outcomes, it may be more appropriate to consider physical activity as a continuous variable. This would better allow researchers to characterize the shape of the dose-response curves (e.g., linear, curvilinear).⁸⁶

In summary, despite the well established relation of physical activity with a number of health measures in children and youth, there is limited evidence for the minimal or optimal volume of physical activity required for good health. This has made it difficult for researchers and public health policy makers to develop evidence-based recommendations on the appropriate volume of physical activity for the pediatric population.

2.5.2 Frequency of Physical Activity

The recommended frequency of physical activity participation is consistent across recent physical activity guidelines, which advocate daily participation for school-aged children and youth (Table 1). However, there is no evidence to support or refute this

recommendation, and as a result it is not clear if physical activity needs to take place on a daily basis. For instance, would it make any difference if the accumulated 7 hours/week, of physical activity over a week by being active for an hour on a daily basis, or if the child accumulated 7 hours in the week but was only active on 5 days?

The other important aspect related to the frequency of physical activity is how these minutes of physical activity are accrued throughout the day. Should the child/youth be active on several occasions throughout the day, or should they focus more on participating in a few longer bouts of activity? Physical activity in youngsters, especially young children, tends to be very sporadic in nature (e.g., a few minutes of play here and there) rather than the structured and continuous physical activity that is typically observed in adults (e.g., one bout of exercise that is several minutes in length).⁸⁷ In fact, one report in a small sample (n=20) of Canadian youth indicated that sporadic activity (bouts lasting <10 minutes) accounted for ~68% of the total volume of physical activity.⁸⁸ Of the published physical activity guidelines for children and youth, only the Canadian guidelines include a stipulation as to how the daily physical activity should be accumulated. Specifically, the Canadian guidelines recommend that children and youth should accumulate physical activity in bouts of at least 5 to 10 minutes in length.^{19, 20} Although this recommendation is an important part of the Canadian guidelines, it is unknown if physical activity accrued in bouts confers a greater health benefit than sporadic physical activity. To date, no studies within children and youth have explored the independent effects of bouts of physical activity and sporadic physical activity on health. Determining whether bouts of physical activity offer additional health benefits

has important public health implications with respect to the promotion of physical activity.

2.5.3 Intensity of Physical Activity

By and large physical activity recommendations for children and youth advocate participation in moderate-to-vigorous physical activity (Table 1). Only the Canadian guidelines^{19,20} stipulate the amount of time youth should increase participation at each intensity (low, moderate, and vigorous) of physical activity (Table 1). Ascertaining the intensity of physical activity which confers the greatest health benefit provides another key component required for evidence-informed physical activity recommendations. A limited amount of research has focused on deciphering the role of physical activity intensity in relation to cardiometabolic health in children and youth.

2.5.3.1 Obesity

Findings from physical activity interventions provide some insight into the influence of the intensity of activity in the physical activity-adiposity relation. When matched for energy expenditure, the intensity of physical activity was not found to influence the effectiveness of a weight loss intervention in obese 13 to 16 year olds with percent body fat decreasing by similar amounts in groups participating in either moderate or vigorous intensity activity.⁴⁶ This finding is not surprising considering that the caloric expenditure was tightly controlled between the moderate and vigorous intensity intervention groups. The implication is that it is much easier for previously inactive individuals to participate in a moderate intensity versus a vigorous intensity physical activity program. However, it must be noted that these results may not hold true at the population level since the study was limited to obese individuals.

Findings from cross-sectional studies provide some evidence regarding the influence of physical activity intensity in relation to obesity. In a sample of 421 16-year-olds, vigorous intensity physical activity, but not moderate intensity physical activity, was found to be a significant predictor of body fat percentage.³⁸ By comparison, the results from a cross-sectional study in a large (n=5595) sample of 12-year olds found a significant inverse relation between total (e.g., all intensities) and moderate-to-vigorous intensity physical activity with fat mass.² However, when total and moderate-to-vigorous intensity physical activity were included in the same model only the relation between moderate-to-vigorous intensity physical activity and fat mass remained significant.²

2.5.3.2 Blood Lipids and Lipoproteins

Findings from a meta-analysis of 12 studies indicate that the intensity of physical activity influences low density lipoprotein cholesterol whereby greater decreases are observed with higher training intensities.⁷⁶ However, physical activity intensity does not appear to influence changes in other blood lipids/lipoproteins (e.g., high density lipoprotein cholesterol, triglycerides).⁷⁶ There is an absence of observational studies that have appropriately determined the role of physical activity intensity on lipids and lipoproteins. Clearly, further research is required to determine the relation between physical activity intensity and blood lipids and lipoproteins.

2.5.3.3 Blood Pressure

A limited number of studies have examined the influence of physical activity intensity on blood pressure in children and youth. Systolic blood pressure decreased by ~0.5 mmHg with every 15 minute increase in moderate-to-vigorous intensity physical activity, after adjusting for total activity level, in a sample of 11- to 12-year-olds.⁸² Total

physical activity has also been found to be inversely related to systolic and diastolic blood pressure in 9- and 15-year-olds.¹ At this time it is unclear if physical activity intensity alters the relation between physical activity volume and blood pressure.

2.5.3.4 Metabolic Syndrome

Moderate, moderate-to-vigorous, and vigorous intensity physical activity were all found to be inversely related to clustered metabolic risk score in a sample of 9- and 15-year-olds from Sweden.⁴⁰ An inverse relation was also observed between total physical activity and clustered cardiometabolic risk score in 9- and 15-year-olds from Denmark, Estonia, and Portugal.¹ Additional research is required to elucidate the influence of physical activity intensity in relation to the metabolic syndrome in youth.

2.5.3.5 Summary

Because of the limited research available, coupled with the discrepant findings in the few available studies, the influence of intensity of physical activity most beneficial for health in children and youth remains unclear. Most of the observational studies that have been conducted have relied on self-reported measures of physical activity intensity, which is a substantive issue given that children and youth have difficulty accurately determining physical activity intensity.⁸⁴ In order to ascertain the influence of physical activity intensity in relation to health measures, objective measures of intensity are needed. Recently there has been an increased reliance on objective measures of physical activity in the literature (e.g., accelerometers, as used in many of the observational studies reviewed in this section^{1, 2, 38, 40, 82}) which permit the accurate measurement of physical activity intensity. Therefore, future research should be able to more clearly and

definitively determine if the intensity of physical activity is an important health determinant in children and youth.

2.5.4 Relation between Physical Activity and Sedentary Behaviour

It is widely speculated that increased time spent in front of the television and computer screen in recent decades, as a measure of sedentary behaviour, has displaced time that children and youth would have previously spent engaging in physical activity.⁸⁹ Deciphering the relation between physical activity and sedentary behaviour has important public health implications in that it is important to know whether guidelines should target one or both of these behaviours.

Studies examining the relationship between screen time and physical activity report conflicting results and do not all support the displacement theory. In fact, the number of studies reporting significant relationships between these behaviours^{58, 90-92} is comparable to the number reporting no associations.⁹³⁻⁹⁶ Although there is no clear indication of what factor(s) accounts for the discrepancy, it may in part be explained by inconsistencies in the measures of screen time. All of the studies reporting a relation between physical activity only measured television viewing^{58, 90-92} whereas three of the four studies reporting no association measured television and computer/video game use.⁹⁴⁻⁹⁶ Discrepancies in findings may also be related to the lack of context specific physical activity measures. In young people organized and unorganized forms of physical activity are poorly related, as is the amount of physical activity performed in the school and home environments.^{97, 98} Because screen time is largely accumulated in an unstructured way at home, it is possible that the use of global measures of total physical activity has not permitted appropriate characterization of the screen time-activity relation.

Intervention studies provide valuable insight into the relation between screen time and physical activity. Three interventions designed to reduce television all reduced screen time,^{44, 60, 99} but only one observed significant improvements in physical activity.⁹⁹ One study⁶⁰ only targeted screen time whereas the other two targeted both screen time and physical activity.^{44, 99} A key distinguishing feature of the intervention that observed positive changes in both behaviours was the inclusion of parents in the education sessions and raises the question about the potential importance parents may have in the adoption of active behaviours.

Although a strong relation between physical activity and screen time is not evident, findings from several studies indicate that relations between physical activity and screen time with health outcomes are independent of the other behaviour (e.g., the relation between physical activity and obesity is independent of screen time).⁵⁷ Youth meeting neither screen time nor physical activity guidelines were significantly more likely (3.00, 1.44-6.26 and 4.39, 1.47-13.12, odds ratios and 95% confidence intervals for girls and boys, respectively) to be overweight compared to youth meeting both guidelines.¹⁰⁰ These findings are contrasted by results from another study completed in 9- to 10- and 15- to 16-year-olds which found that the relation between television and clustered metabolic risk score (the sum of z-score for metabolic risk factors such as blood pressure, triglycerides) was no longer significant after adjustment for physical activity level.⁵⁷ Physical activity and television have also been found to be independently related to obesity in grade 6 to 10 students in Canada as part of the 2001/02 HBSC survey.^{5, 10}

In view of the fact that health outcomes such as obesity are positively related to screen time^{8-11, 57} and inversely related to physical activity,^{1, 2, 10, 38, 41} deciphering the

relation between these behaviours is critical for the development of appropriate public health recommendations. Even though the relationship between physical activity and screen time is unclear, considering that each behaviour may independently influence health, it only seems prudent for recommendations to think about including components related to both behaviours.

2.5.5 Volume of Screen Time

Similar to the physical activity literature, the volume of screen time associated with poor health is unclear. Canadian and American guidelines both recommend limiting screen time to no more than 2 hours per day (Table 2); however, even upon extensive review of the scientific papers that outline screen time recommendations, it is not clear where the 2 hour per day threshold came from. At the time when screen time recommendations were made in the 1990's, there was a paucity of dose-response studies examining the relationship between screen time with physical and psycho-social health outcomes. Furthermore, the only physical health outcome examined in the literature prior to the development of the screen time guidelines was obesity. If the goal of guidelines is to improve health by recommending behaviours associated with decreased health risk, it seems prudent to explore the dose-response relationship between screen time and several health outcomes.

Excessive time spent watching television and playing computer/video games has consistently been linked to obesity in several studies, as reviewed in detail elsewhere.⁵⁷ The positive relation between television and adiposity was first identified back in the mid 1980s when Dietz and colleagues⁹ reported a 2% increase in the prevalence of obesity with each additional daily hour of television. Watching television for ≥ 2 or ≥ 3 hours per

day has been found to increase the likelihood of being overweight or obese, respectively.¹² Another study reported that watching television for 3 hours per day increased the likelihood of being overweight/obese in females (2.83, 1.29-6.24; odds ratio, 95% confidence intervals) while watching ≥ 5 hours of television per day increased the likelihood of being overweight/obese in males (2.63, 1.01-6.85; odds ratio, 95% confidence intervals).¹¹ A positive relation between television and overweight was observed in 23 of the 34 countries that participated in the 2001/02 HBSC in that the prevalence of overweight increased as television viewing (hours per day) increased.⁵ For example, in Canadian youth the odds of overweight increased by 15% (1.09-1.21, 95% confidence intervals) with every hour of television.⁵ As the dose of screen time associated with obesity in these studies is inconsistent, it is difficult to ascertain a specific dose of screen time that should be recommended.

There is some solace in the fact that interventions have successfully reduced screen time (television and/or videogame use) and improved body composition.^{44, 60, 99} Interventions, especially those completed in overweight youth, illustrate the benefit to reducing screen time as part of treatment plan for overweight youth. However, these studies do not provide any information regarding the volume of screen time that should be recommended for prevention.

In summary, there is a lack of dose-response studies suitable for use in the development of screen time guidelines for youth. Obesity is the only physical health outcome that has been considered in relation to excessive screen time. Therefore, further research is needed to elucidate the dose-response relation between volume of screen time and health outcomes, and particularly for outcomes other than obesity.

2.5.6 Incidental Movement

To date neither physical activity (Table 1) nor screen time (Table 2) guidelines contain recommendations about incidental movement. Incidental movement refers to movement that falls below an intensity that would normally be considered as physical activity (e.g., fidgeting, walking around the home). Only a small portion of the day, even amongst active individuals, is spent engaging in physical activity. Furthermore, physical activity accounts for only a fraction of total daily energy expenditure.¹⁰¹ With the majority of the day spent below the physical activity threshold, the energy expenditure accumulated through incidental movement could be quite meaningful with potential long term effects on adiposity and other cardiometabolic health measures.

Only recently has attention been given to the possible influence of incidental movement on health. Two studies completed in adults found an inverse relation between incidental movement and adiposity.^{102, 103} These studies were small in size ($n \leq 20$) and only included inactive individuals.^{102, 103} The first of these study examined the influence of non-exercise activity energy expenditure in the resistance to fat gain in an overfeeding situation.¹⁰² A negative correlation ($r = -0.77$, $p < 0.001$) was found between fat gain and change in activity thermogenesis, a measure of incidental movement.¹⁰² In the second study, daily energy expenditure and incidental movement were assessed in 10 obese and 10 lean participants over 10 days. Within this study a negative correlation ($r^2 = -0.52$) was found between percent body fat and body movement, with obese participants seated an average of 164 minutes longer per day.¹⁰³ Unfortunately, these studies offer little insight into the possible influence of physical activity in the incidental movement-health relation as they were limited to sedentary individuals. However, the relation observed

between incidental movement and obesity in these adult studies does raise questions regarding the possible benefit of activity level during “sedentary” time, at least with respect to obesity. Future research in this topic area is clearly warranted, particularly among children and youth.

2.6 Summary

In general, the research available to develop well-informed physical activity and screen time guidelines for children and youth is lacking. Greater consideration needs to be given to the minimal and optimal volume of physical activity, the appropriate intensity of physical activity, and the necessity of accumulating physical activity in bouts. Greater consideration also needs to be given to the effects of sedentary time, which includes screen time and incidental movement, on the health of children and youth. Consequently, the research outlined in this thesis aims to provide evidence that will better inform public health recommendations for physical activity and screen time.

References

1. Andersen LB, Harro M, Sardinha LB, et al. Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study). *Lancet* 2006;368(9532):299-304.
2. Ness AR, Leary SD, Mattocks C, et al. Objectively measured physical activity and fat mass in a large cohort of children. *Plos Medicine* 2007;4(3):476-84.
3. Wareham NJ, van Sluijs EM, Ekelund U. Physical activity and obesity prevention: a review of the current evidence. *Proc Nutr Soc* 2005;64(2):229-47.
4. Dencker M, Thorsson O, Karlsson MK, et al. Daily physical activity related to body fat in children aged 8-11 years. *J Pediatr* 2006;149(1):38-42.
5. Janssen I, Katzmarzyk PT, Boyce WF, et al. Comparison of overweight and obesity prevalence in school-aged youth from 34 countries and their relationships with physical activity and dietary patterns. *Obes Rev* 2005;6(2):123-32.
6. Molnar D, Livingstone B. Physical activity in relation to overweight and obesity in children and adolescents. *Eur J Pediatr* 2000;159 Suppl 1:S45-55.
7. Dowda M, Ainsworth BE, Addy CL, Saunders R, Riner W. Environmental influences, physical activity, and weight status in 8- to 16-year-olds. *Arch Pediatr Adolesc Med* 2001;155(6):711-7.
8. Andersen RE, Crespo CJ, Bartlett SJ, Cheskin LJ, Pratt M. Relationship of physical activity and television watching with body weight and level of fatness among children: results from the Third National Health and Nutrition Examination Survey. *JAMA* 1998;279(12):938-42.

9. Dietz WH, Jr., Gortmaker SL. Do we fatten our children at the television set? Obesity and television viewing in children and adolescents. *Pediatrics* 1985;75(5):807-12.
10. Janssen I, Katzmarzyk PT, Boyce WF, King MA, Pickett W. Overweight and obesity in Canadian adolescents and their associations with dietary habits and physical activity patterns. *J Adolesc Health* 2004;35(5):360-7.
11. Crespo CJ, Smit E, Troiano RP, Bartlett SJ, Macera CA, Andersen RE. Television watching, energy intake, and obesity in US children: results from the third National Health and Nutrition Examination Survey, 1988-1994. *Arch Pediatr Adolesc Med* 2001;155(3):360-5.
12. Tremblay MS, Willms JD. Is the Canadian childhood obesity epidemic related to physical inactivity? *Int J Obes Relat Metab Disord* 2003;27(9):1100-5.
13. Raitakari OT, Taimela S, Porkka KV, et al. Associations between physical activity and risk factors for coronary heart disease: the Cardiovascular Risk in Young Finns Study. *Med Sci Sports Exerc* 1997;29(8):1055-61.
14. Brage S, Wedderkopp N, Ekelund U, et al. Objectively measured physical activity correlates with indices of insulin resistance in Danish children. The European Youth Heart Study (EYHS). *Int J Obes Relat Metab Disord* 2004;28(11):1503-8.
15. Malina RM. Physical activity and fitness: pathways from childhood to adulthood. *Am J Hum Biol* 2001;13(2):162-72.
16. Twisk JW, Kemper HC, van Mechelen W. Tracking of activity and fitness and the relationship with cardiovascular disease risk factors. *Med Sci Sports Exerc* 2000;32(8):1455-61.

17. Twisk JW. Physical activity guidelines for children and adolescents: a critical review. *Sports Med* 2001;31(8):617-27.
18. Sallis J, Patrick K. Physical Activity Guidelines for Adolescents: Consensus Statement. *Ped Exerc Sci* 1994;6:302-14.
19. Health Canada and Canadian Society for Exercise Physiology. Canada's Physical Activity Guide to Healthy Active Living: Family Guide to Physical Activity for Youth 6-9 Years of Age. In. Ottawa, ON: Minister of Health; 2002.
20. Health Canada and the Canadian Society for Exercise Physiology. Canada's Physical Activity Guide to Healthy Active Living: Family Guide to Physical Activity for Youth 10-14 Years of Age. In. Ottawa, ON: Minister of Health; 2002.
21. Physical Activity and Young People. 2008. (Accessed February 18, 2008, at http://www.who.int/dietphysicalactivity/factsheet_young_people/en/index.html.)
22. Strong WB, Malina RM, Blimkie CJ, et al. Evidence based physical activity for school-age youth. *J Pediatr* 2005;146(6):732-7.
23. Biddle S, Sallis J, Cavill N. Policy framework for young people and health-enhancing physical activity. In: Biddle S, Sallis J, Cavill N, eds. *Young and Active? Young People and Health-Enhancing Physical Activity: Evidence and Implications*. London: Health Education Authority; 1998:3-16.
24. Department of Health and Aging. National Physical Activity Guidelines for Australians. In: Government A, ed. Canberra: Canberra, Australia; 1999.
25. Brown JD, Witherspoon EM. The mass media and American adolescents' health. *J Adolesc Health* 2002;31(6 Suppl):153-70.

26. Hamilton MT, Hamilton DG, Zderic TW. Role of low energy expenditure and sitting in obesity, metabolic syndrome, type 2 diabetes, and cardiovascular disease. *Diabetes* 2007;56(11):2655-67.
27. Preamble to the Constitution of the World Health Organization as adopted by the International Health Conference NY, 19-22 June, 1946; signed on 22 July 1946 by the representatives of 61 States (Official Records of the World Health Organization, no. 2, p. 100) and entered into force on 7 April 1948.
28. Age-standardized mortality rates by selected causes, by sex. 2007. (Accessed October 15, 2008, 2008, at <http://www40.statcan.ca/101/cst01/health30a.htm>.)
29. Active Healthy Kids Canada. Canada's Report Card on Physical Activity for Children & Youth- 2008; 2008.
30. Glimour H. Physically Active Canadians. *Health Rep* 2007;18(3):45-65.
31. Statistics Canada. Children's participation in physical activities, in hours per week, by sex, household population aged 6 to 11, Canadian Community Health Survey cycle 2.2. In: CANSIM: Canadian Community Health Survey, Nutrition, 2004; 2005.
32. Currie C, Gabhainn S, Godeau E, et al. Inequalities in Young People's Health: HBSC International Report from the 2005/2006 Survey; 2008.
33. U.S. Department of Health and Human Services and US Department of Agriculture. Dietary guidelines for Americans 2005. Washington, D.C.: Department of Health and Human Services; 2005.
34. Byers T, Nestle M, McTiernan A, et al. American Cancer Society guidelines on nutrition and physical activity for cancer prevention: Reducing the risk of cancer with healthy food choices and physical activity. *CA Cancer J Clin* 2002;52(2):92-119.

35. Corbin CB, Pangrazi RP. Physical Activity for Children: a statement of guidelines for children aged 5-12. 2nd ed. Reston, VA: National Academy for Sport and Physical Education; 2004.
36. Canadian Fitness and Lifestyle Research Institute. Kids CAN PLAY! Encouraging children to be active at home, at school, and in their communities; 2008 May 2008.
37. Olds T, Ridley K, Wake M, et al. How should activity guidelines for young people be operationalised? *Int J Behav Nutr Phys Act* 2007;4:43.
38. Gutin B, Yin Z, Humphries MC, Barbeau P. Relations of moderate and vigorous physical activity to fitness and fatness in adolescents. *Am J Clin Nutr* 2005;81(4):746-50.
39. Rizzo NS, Ruiz JR, Oja L, Veidebaum T, Sjostrom M. Associations between physical activity, body fat, and insulin resistance (homeostasis model assessment) in adolescents: the European Youth Heart Study. *Am J Clin Nutr* 2008;87(3):586-92.
40. Rizzo NS, Ruiz JR, Hurtig-Wennlof A, Ortega FB, Sjostrom M. Relationship of physical activity, fitness, and fatness with clustered metabolic risk in children and adolescents: the European youth heart study. *J Pediatr* 2007;150(4):388-94.
41. Moore LL, Gao D, Bradlee ML, et al. Does early physical activity predict body fat change throughout childhood? *Prev Med* 2003;37(1):10-7.
42. Twisk JW, Kemper HC, van Mechelen W. The relationship between physical fitness and physical activity during adolescence and cardiovascular disease risk factors at adult age. The Amsterdam Growth and Health Longitudinal Study. *Int J Sports Med* 2002;23 Suppl 1:S8-14.

43. Twisk JW, Kemper HC, Van Mechelen W, Post GB. Clustering of risk factors for coronary heart disease. the longitudinal relationship with lifestyle. *Ann Epidemiol* 2001;11(3):157-65.
44. Gortmaker SL, Peterson K, Wiecha J, et al. Reducing obesity via a school-based interdisciplinary intervention among youth: Planet Health. *Arch Pediatr Adolesc Med* 1999;153(4):409-18.
45. Atlantis E, Barnes EH, Singh MA. Efficacy of exercise for treating overweight in children and adolescents: a systematic review. *Int J Obes (Lond)* 2006;30(7):1027-40.
46. Gutin B, Barbeau P, Owens S, et al. Effects of exercise intensity on cardiovascular fitness, total body composition, and visceral adiposity of obese adolescents. *Am J Clin Nutr* 2002;75(5):818-26.
47. Patrick K, Norman GJ, Calfas KJ, et al. Diet, physical activity, and sedentary behaviors as risk factors for overweight in adolescence. *Arch Pediatr Adolesc Med* 2004;158(4):385-90.
48. Gutin B, Cucuzzo N, Islam S, Smith C, Stachura ME. Physical training, lifestyle education, and coronary risk factors in obese girls. *Med Sci Sports Exerc* 1996;28(1):19-23.
49. Berenson GS, Srinivasan SR, Bao W, Newman WP, 3rd, Tracy RE, Wattigney WA. Association between multiple cardiovascular risk factors and atherosclerosis in children and young adults. The Bogalusa Heart Study. *N Engl J Med* 1998;338(23):1650-6.

50. Bao W, Threefoot SA, Srinivasan SR, Berenson GS. Essential hypertension predicted by tracking of elevated blood pressure from childhood to adulthood: the Bogalusa Heart Study. *Am J Hypertens* 1995;8(7):657-65.
51. Chen W, Srinivasan SR, Li S, Xu J, Berenson GS. Clustering of Long-term Trends in Metabolic Syndrome Variables from Childhood to Adulthood in Blacks and Whites: The Bogalusa Heart Study. *Am J Epidemiol* 2007;166(5):527-33.
52. Morrison JA, Friedman LA, Wang P, Glueck CJ. Metabolic syndrome in childhood predicts adult metabolic syndrome and type 2 diabetes mellitus 25 to 30 years later. *J Pediatr* 2008;152(2):201-6.
53. Malina RM. Tracking of physical activity and physical fitness across the lifespan. *Res Q Exerc Sport* 1996;67(3 Suppl):S48-57.
54. Sesso HD, Paffenbarger RS, Jr., Lee IM. Physical activity and coronary heart disease in men: The Harvard Alumni Health Study. *Circulation* 2000;102(9):975-80.
55. Paffenbarger RS, Jr., Hyde RT, Hsieh CC, Wing AL. Physical activity, other life-style patterns, cardiovascular disease and longevity. *Acta Med Scand Suppl* 1986;711:85-91.
56. Blair SN, Kampert JB, Kohl HW, 3rd, et al. Influences of cardiorespiratory fitness and other precursors on cardiovascular disease and all-cause mortality in men and women. *Jama* 1996;276(3):205-10.
57. Ekelund U, Brage S, Froberg K, et al. TV viewing and physical activity are independently associated with metabolic risk in children: the European Youth Heart Study. *PLoS Med* 2006;3(12):e488.

58. Eisenmann JC, Bartee RT, Wang MQ. Physical activity, TV viewing, and weight in U.S. youth: 1999 Youth Risk Behavior Survey. *Obes Res* 2002;10(5):379-85.
59. Hancox RJ, Milne BJ, Poulton R. Association between child and adolescent television viewing and adult health: a longitudinal birth cohort study. *Lancet* 2004;364(9430):257-62.
60. Robinson TN. Reducing children's television viewing to prevent obesity: a randomized controlled trial. *JAMA* 1999;282(16):1561-7.
61. Tremblay MS, Shephard RJ, Brawley LR. Research that informs Canada's physical activity guides: an introduction. *Can J Public Health* 2007;98 Suppl 2:S1-8.
62. American College of Sports Medicine. Opinion Statement on physical fitness in children and youth. *Med Sci Sports Exerc* 1988;20:422-3.
63. Sallis JF, Patrick K. Physical activity guidelines for adolescents: consensus statement. *Ped Exer Science* 1994;6(4):302-14.
64. Physical activity and cardiovascular health. NIH Consensus Development Panel on Physical Activity and Cardiovascular Health. *Jama* 1996;276(3):241-6.
65. U.S. Department of Health and Human Services. Physical Activity and Health: A Report of the Surgeon General. Atlanta, GA: Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion; 1996.
66. Berg F, Buechner J, Parham E. Guidelines for childhood obesity prevention programs: promoting healthy weight in children. *J Nutr Educ Behav* 2003;35(1):1-4.

67. U.S. Department of Health and Human Services, U.S. Department of Agriculture. Dietary Guidelines for Americans, 2005. In. 6th ed. Washington, DC: U.S. Government Printing Office; January, 2005.
68. Janssen I. Physical activity guidelines for children and youth. *Applied Physiology Nutrition and Metabolism* 2007;32(2E):S109-S21.
69. Nelson MC, Gordon-Larsen P. Physical activity and sedentary behavior patterns are associated with selected adolescent health risk behaviors. *Pediatrics* 2006;117(4):1281-90.
70. Impact of media use on children and youth. *Paediatrics & Child Health* 2003;8(5):301-6.
71. American Academy of Pediatrics: Children, adolescents, and television. *Pediatrics* 2001;107(2):423-6.
72. Healthy Weights for Healthy Kids: Report of the Standing Committee on Health. 2007.
73. Hasselstrom H, Hansen SE, Froberg K, Andersen LB. Physical fitness and physical activity during adolescence as predictors of cardiovascular disease risk in young adulthood. Danish Youth and Sports Study. An eight-year follow-up study. *Int J Sports Med* 2002;23 Suppl 1:S27-31.
74. Boreham C, Twisk J, Neville C, Savage M, Murray L, Gallagher A. Associations Between Physical Fitness and Activity Patterns During Adolescence and Cardiovascular Risk Factors in Young Adulthood: The Northern Ireland Young Hearts Project. *International Journal of Sports Medicine* 2002(S1):22.

75. Lefevre J, Philippaerts R, Delvaux K, et al. Relation between cardiovascular risk factors at adult age, and physical activity during youth and adulthood: the Leuven Longitudinal Study on Lifestyle, Fitness and Health. *Int J Sports Med* 2002;23 Suppl 1:S32-8.
76. Kelley GA, Kelley KS. Aerobic exercise and lipids and lipoproteins in children and adolescents: a meta-analysis of randomized controlled trials. *Atherosclerosis* 2007;191(2):447-53.
77. Tolfrey K, Jones AM, Campbell IG. Lipid-lipoproteins in children: an exercise dose-response study. *Med Sci Sports Exerc* 2004;36(3):418-27.
78. Suter E, Hawes MR. Relationship of physical activity, body fat, diet, and blood lipid profile in youths 10-15 yr. *Med Sci Sports Exerc* 1993;25(6):748-54.
79. Katzmarzyk PT, Malina RM, Bouchard C. Physical activity, physical fitness, and coronary heart disease risk factors in youth: the Quebec Family Study. *Prev Med* 1999;29(6 Pt 1):555-62.
80. Kelley GA, Kelley KS. Exercise and Resting Blood Pressure in Children and Adolescents: A Meta-Analysis. *Ped Exerc Sci* 2003;15:83-97.
81. Gidding SS, Barton BA, Dorgan JA, et al. Higher self-reported physical activity is associated with lower systolic blood pressure: the Dietary Intervention Study in Childhood (DISC). *Pediatrics* 2006;118(6):2388-93.
82. Leary SD, Ness AR, Smith GD, et al. Physical activity and blood pressure in childhood: findings from a population-based study. *Hypertension* 2008;51(1):92-8.
83. Fagard RH. Exercise characteristics and the blood pressure response to dynamic physical training. *Med Sci Sports Exerc* 2001;33(6 Suppl):S484-92; discussion S93-4.

84. Adamo KB, Prince SA, Tricco AC, Connor-Gorber S, Tremblay M. A comparison of indirect versus direct measures for assessing physical activity in the pediatric population: A systematic review. *Int J Pediatr Obes* 2008;1-26.
85. Ruiz JR, Rizzo NS, Hurtig-Wennlof A, Ortega FB, Warnberg J, Sjostrom M. Relations of total physical activity and intensity to fitness and fatness in children: the European Youth Heart Study. *Am J Clin Nutr* 2006;84(2):299-303.
86. Bagnardi V, Zambon A, Quatto P, Corrao G. Flexible meta-regression functions for modeling aggregate dose-response data, with an application to alcohol and mortality. *Am J Epidemiol* 2004;159(11):1077-86.
87. Welk GJ, Corbin CB, Dale D. Measurement issues in the assessment of physical activity in children. *Res Q Exerc Sport* 2000;71(2 Suppl):S59-73.
88. Esliger DW, Tremblay MS. Physical activity and inactivity profiling: the next generation. *Can J Public Health* 2007;98 Suppl 2:S195-207.
89. Bryant MJ, Lucove JC, Evenson KR, Marshall S. Measurement of television viewing in children and adolescents: a systematic review. *Obes Rev* 2007;8(3):197-209.
90. DuRant RH, Baranowski T, Johnson M, Thompson WO. The relationship among television watching, physical activity, and body composition of young children. *Pediatrics* 1994;94(4 Pt 1):449-55.
91. Marshall SJ, Biddle SJ, Gorely T, Cameron N, Murdey I. Relationships between media use, body fatness and physical activity in children and youth: a meta-analysis. *Int J Obes Relat Metab Disord* 2004;28(10):1238-46.

92. Motl RW, McAuley E, Birnbaum AS, Lytle LA. Naturally occurring changes in time spent watching television are inversely related to frequency of physical activity during early adolescence. *J Adolesc* 2006;29(1):19-32.
93. Robinson TN, Hammer LD, Killen JD, et al. Does television viewing increase obesity and reduce physical activity? Cross-sectional and longitudinal analyses among adolescent girls. *Pediatrics* 1993;91(2):273-80.
94. Gordon-Larsen P, McMurray RG, Popkin BM. Determinants of adolescent physical activity and inactivity patterns. *Pediatrics* 2000;105(6):E83.
95. Berkey CS, Rockett HR, Gillman MW, Colditz GA. One-year changes in activity and in inactivity among 10- to 15-year-old boys and girls: relationship to change in body mass index. *Pediatrics* 2003;111(4 Pt 1):836-43.
96. Taveras EM, Field AE, Berkey CS, et al. Longitudinal relationship between television viewing and leisure-time physical activity during adolescence. *Pediatrics* 2007;119(2):e314-9.
97. Mota J, Santos P, Guerra S, Ribeiro JC, Duarte JA. Patterns of daily physical activity during school days in children and adolescents. *Am J Hum Biol* 2003;15(4):547-53.
98. Trost SG, Pate RR, Freedson PS, Sallis JF, Taylor WC. Using objective physical activity measures with youth: how many days of monitoring are needed? *Med Sci Sports Exerc* 2000;32(2):426-31.
99. Epstein LH, Paluch RA, Gordy CC, Dorn J. Decreasing sedentary behaviors in treating pediatric obesity. *Arch Pediatr Adolesc Med* 2000;154(3):220-6.

100. Laurson KR, Eisenmann JC, Welk GJ, Wickel EE, Gentile DA, Walsh DA. Combined influence of physical activity and screen time recommendations on childhood overweight. *J Pediatr* 2008;153(2):209-14.
101. Goran MI, Treuth MS. Energy expenditure, physical activity, and obesity in children. *Pediatr Clin North Am* 2001;48(4):931-53.
102. Levine JA, Eberhardt NL, Jensen MD. Role of nonexercise activity thermogenesis in resistance to fat gain in humans. *Science* 1999;283(5399):212-4.
103. Levine JA, Lanningham-Foster LM, McCrady SK, et al. Interindividual variation in posture allocation: possible role in human obesity. *Science* 2005;307(5709):584-6.

CHAPTER 3

Manuscript 1

Dose-Response Relation Between Physical Activity and Blood Pressure in Youth.

This manuscript is published in *Medicine & Science in Sports & Exercise* (2008; 40(6):1007-12) and has been presented in a format consistent with the journal requirements.

Guideline component: This manuscript explores the volume component of the physical activity guidelines by examining the dose-response relation between physical activity and blood pressure in youth.

ABSTRACT

Background: The dose-response relationship between physical activity (PA) and cardiovascular health in children and adolescents is unclear. Blood pressure (BP) is a practical and useful measure of cardiovascular health in youth.

Purpose: To examine the dose-response relationship between objectively measured PA and BP in children and adolescents.

Methods: The sample included 1170 youth aged 8-17 years from the 2003-2004 U.S. National Health and Nutrition Examination Survey. PA was measured using Actigraph accelerometers over 7 days. Thresholds of 2000 and 3000 counts per minute were used to denote those minutes where the participants were engaged in total PA and moderate-to-vigorous intensity PA, respectively. BP was measured using standard procedures. Systolic and diastolic BP values were adjusted for age, height, and sex. Participants with adjusted BP values $\geq 90^{\text{th}}$ percentile were considered to have hypertension. Thirty six fractional polynomial regression models were used to obtain the dose-response curve that best fit the relation between PA with systolic BP, diastolic BP, and hypertension.

Results: Inverse dose-response relations were observed between total and moderate-to-vigorous PA with systolic and diastolic BP. The slopes of the curves were modest indicating a minimal influence of PA on mean BP values. The likelihood of having hypertension decreased in a curvilinear manner with increasing minutes of PA. At 30 and 60 min/d of moderate-to-vigorous PA the odd ratios (95% confidence intervals) for hypertension were 0.50 (0.33-0.72) and 0.37 (0.26-0.47), respectively, in comparison to 1 minute of PA.

Conclusions: A modest dose-response relation was observed between PA and mean systolic and diastolic BP values. PA did, however, have a strong gradient effect on BP when predicting hypertensive values. These results support the public health recommendation that children and youth accumulate at least 60 minutes of moderate-to-vigorous PA daily.

Keywords: accelerometer, hypertension, children, adolescents

INTRODUCTION

Cardiovascular disease is a progressive disease that starts in childhood.¹⁻⁴ Elevated blood pressure (BP) during childhood and adolescence increases the risk of hypertension in adulthood,^{5, 6} when more severe forms of cardiovascular disease also occur quite frequently. It is therefore important to prevent the development of hypertension at young ages.

Physical activity (PA) is key component of the therapeutic lifestyle changes recommended for preventing and treating prehypertension and hypertension in children and youth.^{7, 8} The American Heart Association recommends that children and youth participate in at least 60 minutes of moderate-to-vigorous PA daily for cardiovascular health promotion.⁹ The review of PA interventions completed during the development of the Centers for Disease Control and Prevention sponsored 2005 Evidence Based PA guidelines for children and youth suggests that at least 30 minutes of PA at a frequency of 3 times per week and intensity of 80% of maximal heart rate is required to lower BP.¹⁰ While it is recognized that PA has important effects on BP, the specific PA guidelines and recommendations mentioned above were developed based on the best available evidence, which in the case for BP and most other health outcomes in children and youth, is not the ideal type and amount of evidence.¹¹

Dose-response studies are particularly useful for determining the minimal and optimal amount of PA required for good health. To our knowledge only two studies^{12, 13} have examined the dose-response relation between PA and BP in children and adolescents with only one study finding a relation.¹² This study found that for every 100 metabolic-equivalent (MET) hour increase in PA, systolic BP decreased in a linear

manner by 1.15 mmHg.¹² Although a dose-response relation was seen, the PA measurement unit (MET) does not provide information that can be transformed into an understandable public health message (e.g., minutes of PA per day). The self-reported PA questionnaire used in that study was also subject to recall bias,¹⁴ and likely resulted in an overestimation of actual PA levels. Objective measures of PA, such as those obtained by accelerometers, offer the advantage of being able to measure the frequency, intensity, and duration of activity.

Although PA may play an important role in the prevention of hypertension, the dose-response relation between PA and BP in the pediatric age group is unclear. Therefore, the purpose of the study was to examine the dose-response relation between objectively measured PA, BP, and hypertension in children and youth.

METHODS

The study sample consisted of participants from the 2003-2004 National Health and Nutrition Examination Surveys (NHANES). NHANES is a representative cross-sectional survey of the U.S. population.¹⁵ The secondary analysis presented here was approved by the Queen's University Health Sciences Research Ethics Board. NHANES participants were identified using a complex, stratified, multistage, probability sampling design.¹⁵ The present study was limited to those aged 8 to 17 years who completed both the home and mobile exam center (MEC) components of the survey required for the analysis. Informed consent was obtained from all the parents and participants, and the protocol was approved by the National Center for Health Statistics. A more detailed description of the NHANES methodology is provided in Appendix B.

Physical Activity. PA was measured using Actigraph 7124 activity monitors (Actigraph, Ft. Walton Beach, FL). A more detailed description of the use of activity monitors for the assessment of physical activity is provided in Appendix D. Activity monitors can be used to objectively measure the duration and intensity of PA under free-living conditions.^{16,17} Monitors were provided to subjects during the MEC exam, were programmed to start recording at midnight of the day following the exam, and recorded activity for the following 7 days. Participants were instructed to wear the monitor during waking hours except when it could get wet. Monitors were attached to elasticized fabric belts and worn on the right hip.

The Actigraph is a uniaxial monitor that measures the intensity of movement averaged over 1 minute sampling epochs. Data from each monitor was downloaded by the Centers for Disease Control and Prevention and checked for spurious data (e.g., biologically implausible values), which were subsequently removed. We did not remove additional spurious data; however, further data reduction was completed by the authors before analyses were performed. Specifically, the current study only included subjects with at least 4 days of complete monitoring, including at least 1 weekend day. Four days of monitoring has a test-retest reliability of 0.7.¹⁶ A day was considered complete if it included at least 10 hours of wear time.¹⁶ Wear time was determined by filtering activity monitor data and deleting sections of more than 20 minutes of zero counts indicating non-wear time.¹⁸

For each complete day of monitoring, thresholds of 2000 (equivalent to walking ~4.0 km/h) and 3000 (equivalent to walking ~5.6 km/h) counts per minute were used to denote those minutes where the participants were engaged in PA of at least a low

intensity (total PA) and moderate-to-vigorous intensity PA, respectively.¹⁹ The measurement unit of counts per minute is generated based on the magnitude and frequency of movement. The minutes of total and moderate-to-vigorous intensity PA were averaged across all complete days of monitoring to create the final PA variables used for analysis.

There is considerable discrepancy in the literature concerning the accelerometry threshold that should be used to classify PA intensity, and the proposed thresholds often vary by age and gender.²⁰ The 2000 and 3000 counts per minute thresholds used in this study were selected based on available evidence and best judgement of the authors. Although the thresholds used here were developed from a study conducted entirely in adolescent females, similar thresholds have been used for males and females^{21,22} and in youth ranging in age from 6 to 16 years.²² Thresholds were based on metabolic equivalents during activities of daily living (e.g., threshold for moderate-to-vigorous PA based on counts per minute for activity of 3 metabolic equivalents).

Blood Pressure. Measurements were completed at the MEC. Subjects were seated and rested quietly for 5 minutes before 3 BP measures were obtained on the right arm using a mercury sphygmomanometer. Systolic BP was recorded at the first Korotkoff sound and diastolic BP was the point of the last audible Korotkoff sound. Mean BP values were used for all analyses. BP z-scores were calculated based on reference values for age, height, and sex.⁷ Hypertension was defined as having systolic or diastolic levels above the 90th percentile for age, sex and height (considered pre-hypertensive or hypertensive).⁷

Body Mass Index. Height and weight was measured during the MEC to the nearest 0.1 cm and 0.1 kg, respectively, and used to calculate the body mass index (kg/m^2). Subjects were classified as ‘at-risk of overweight’ and ‘overweight’ according to the Centers for Disease Control and Prevention age- and gender-specific cut- points for children and youth of 85th-94th percentiles and $\geq 95^{\text{th}}$ percentile, respectively.²³

Covariates. Covariates included sex, race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, and other), the poverty-to-income ratio (a measure of socioeconomic status), total caloric intake, and smoking status. For caloric intake, participants were queried and reported on type and amount of food and beverages consumed during the 24 hours prior to their examination. Results of the dietary recall were used to estimate total daily caloric intake (kcal/d).²⁴ Smoking status included never smokers, ever smokers, and non-responders. Covariates were selected to be consistent with literature and to control factors that may influence the relation between exposure and outcome.

Statistical Analysis. All analyses were performed using SAS version 9.1 (SAS Institute, Cary, North Carolina) and took into account the sample weights of the NHANES survey. Linear regression was used to examine the relationship between total PA and moderate-to-vigorous PA with systolic BP and diastolic BP. Logistic regression was used to examine the relationship between total PA and moderate-to-vigorous PA with hypertension. In all statistical models, PA was included as a continuous measure in minutes per day. Fractional polynomial models for PA were run to obtain the models that best fit the dose-response relation between PA, BP, and hypertension. The 36 fractional polynomial regression models recommended by Bagnardi et al.²⁵ for examining dose-

response relations were used for the current analysis. This form of analysis is concerned with finding the dose-response curve with the best model fit, rather than determining the significance of the linear relation between the exposure (PA) and outcome (mean BP value or hypertension). For the linear regression analyses, the model with the highest R^2 and smallest error was considered to provide the best fit. For the logistic regression analyses, the model with the lowest Akaike Information Criterion (AIC) was considered to provide the best fit. Sex, age, race/ethnicity, poverty-to-income ratio, total calories, and smoking status were included as covariates in all statistical models. Bootstrapping was used to estimate the 95% confidence intervals for the regression analyses. Because prehypertension/hypertension was not a rare outcome in the study sample (14%), the odds ratios (OR) obtained from logistic regression analyses do not approximate relative risk.²⁶ Therefore, risk ratios (RR) were derived by adjusting OR by the proportion of the outcome in the referent groups (P_0) as follows: $RR=OR/((1-P_0) + (P_0 \times OR))$.²⁶ Samples of linear and logistic regression output are presented in Appendix I and Appendix J, respectively.

RESULTS

There were 2413 participants aged 8 to 17 years in the 2003-2004 NHANES. Acceptable PA measurements were not available for 1197 participants and acceptable BP measurements were not available for 166 participants. The current analyses included the 1170 participants (607 males and 563 females) with complete PA and BP measurements. There were no statistical differences in the body mass index or gender distribution of the

participants who were included or excluded from the analyses. However, the participants included in the analyses were younger and contained a higher proportion of Hispanics.

Basic demographic characteristics of the subjects included in the analyses are presented in Table 1. The majority of the study participants were non-Hispanic white, and 38.4% were classified as either ‘at-risk of overweight’ or ‘overweight’. Subjects participated in 53.0 ± 32.1 min/d (mean \pm SD) and 25.8 ± 20.6 min/d of total PA and moderate-to-vigorous intensity PA, respectively. Mean systolic and diastolic BP values in males were 108.5 ± 10.4 mmHg and 57.0 ± 11.3 mmHg, respectively. The corresponding values in females were 104.1 ± 8.9 mmHg and 58.5 ± 10.6 mmHg. Approximately 14% of the participants were hypertensive (18.1% in males, 9.4% in females). As shown in Table 2, a higher proportion of females participated in less than 30 min/d of total PA compared to males (36.9% vs. 14.8%). The majority of males (88.3%) and females (98.6%) participated in less than 60 min/d of moderate-to-vigorous intensity PA.

Relations between PA and BP were modeled for PA values ranging from 1 min/d to 2 standard deviations above the population mean. An inverse dose-response relationship was observed between total (Figure 1, Panel A) and moderate-to-vigorous PA (Figure 1, Panel B) with systolic BP. Total PA had no effect on systolic BP until approximately 40 min/d after which systolic BP decreased as total PA increased, with no plateau in the effect. Although an inverse relation was observed between total PA, moderate-to-vigorous PA, and systolic BP, the slope of the curve was modest indicating a minimal influence of PA on systolic BP measures. For example, the systolic BP z-score decreased by 0.09 units between 60 and 90 min/d of total PA which is equivalent to 0.93

mmHg. A similar modest dose-response relation was seen between total PA (Figure 1, Panel C) and moderate-to-vigorous PA (Figure 1, Panel D) with diastolic BP. A plateau in the effect of PA on diastolic BP was seen at approximately 80 min/d and 45 min/d for total and moderate-to-vigorous PA, respectively.

The likelihood of hypertension decreased in a curvilinear manner with increasing minutes of total PA (Figure 2, Panel A) and moderate-to-vigorous PA (Figure 2, Panel B). At 30 min/d of moderate-to-vigorous PA the risk ratio (95% confidence intervals (CI)) for hypertension was 0.50 (0.33-0.72) in comparison to 1 minute of PA. At 60 min/d of moderate-to-vigorous PA the risk ratio (95% CI) for hypertension was 0.37 (0.26-0.47). At 30, 60, 90, and 120 min/d of total PA the risk ratios (95% CI) for hypertension were 0.62 (0.41-0.91), 0.48 (0.29-0.75), 0.39 (0.24-0.56), and 0.33 (0.22-0.43), respectively.

DISCUSSION

This study focused on developing dose-response curves that best represent the relation between PA, BP, and hypertension in children and youth. A modest dose-response relation was observed between total and moderate-to-vigorous PA with mean systolic and diastolic BP values. PA did, however, have a strong effect on BP when predicting high risk values in the hypertensive range. At 60 min/d of moderate-to-vigorous PA, the PA volume corresponding to the public health recommendation in many countries,^{10,27,28} the likelihood of hypertension was approximately one third of that observed for one minute of moderate-to-vigorous PA.

The modest nature of the dose-response relation between PA and BP was not unexpected considering the discrepancy in the literature surrounding the effects of PA on BP in children and youth. In a previous study of adolescents with dyslipidemia, a linear dose-response relation was found between self-report PA and systolic BP; PA was not related to diastolic BP.¹² This study did not consider whether the relation between PA and BP was non-linear in nature. Of the two studies in children and youth that examined the relation between PA and BP using an objective measure of PA (e.g., accelerometers),^{21, 29} only one²¹ reported a significant correlation. Neither of these studies used an analysis strategy that adequately explored the dose-response relation between PA and BP.^{21, 29}

A recent meta-analysis of randomized controlled trials reported a similar inconsistency in the effects of PA interventions on lowering BP in children and adolescents.³⁰ The authors suggested that the null effect of PA on BP may have been in part related to the inclusion of normotensive subjects in the intervention trials.³⁰ Out of the 16 groups included in the meta-analysis only 2 were limited to hypertensive subjects.³⁰ A similar observation was made by the authors of an adult based meta-analysis on PA and BP. The adult meta-analysis found PA to have a threefold greater effect on lowering BP in hypertensive compared to normotensive individuals.³¹ The findings from these meta-analyses suggest that PA has a greater effect on high risk BP values. Our results support this contention. The slopes of the dose-response curves between PA and mean BP values were modest, while the slope of the dose-response curves between PA and hypertension were quite steep. That PA has a greater effect on high risk BP values is consistent with the effects of PA on other cardiometabolic risk

factors including blood lipids/lipoproteins³² and insulin resistance.³³ Perhaps it is only intuitive that PA does not positively impact cardiometabolic risk factor values that already fall within the normal healthy range.

In studies of adults it has been reported that the intensity of PA does not significantly contribute to whether or not a PA intervention is able to successfully reduce BP levels.³¹ Conversely, the 2005 Evidence Based PA Guidelines for children and youth suggest that an intensity corresponding to 80% of the maximum heart rate is required in a PA intervention to reduce BP levels in hypertensive children and adolescents.¹⁰ In the current study the nature of the dose-response curve between PA and hypertension was similar for both total and moderate-to-vigorous intensity PA. However, considerably fewer minutes of moderate-to-vigorous intensity PA were required to lower hypertension risk. For instance, the likelihood of hypertension was reduced by approximately 50% at 30 min/d of moderate-to-vigorous PA versus 53 min/d of total PA. Thus, in the development of strategies aimed at preventing and treating hypertension in children and youth, both time and intensity of PA are important factors to consider.

Our results provide support for the 2005 Evidence Based PA Guidelines¹⁰ which recommend that school-aged children and youth accumulate at least 60 minutes of moderate-to-vigorous intensity PA daily. Specifically, we observed a plateau in the relationship between moderate-to-vigorous PA and hypertension risk at approximately 60 min/d. The absence of a plateau in the relationship between total PA and hypertension risk also corroborates the Canadian PA Guidelines for children and youth, which recommends that all children and youth, regardless of their current PA level, increase overall PA by 90 min/d (<http://www.phac-aspc.gc.ca/pau-uap/fitness/downloads.html>).³⁴

³⁵ Given the volume of PA recommended in the Evidence Based PA Guidelines, and the dose-response relation between PA and hypertension observed here, it is very concerning that only 11.7% of the male and 1.4% of the female participants in this study were moderately or vigorously active for at least 60 min/d on average. These findings emphasize the need for the implementation of public health interventions and policies that will substantially improve the PA levels of most children and adolescents. In the development of strategies to increase PA participation, it is important to consider the roles of the family, school, and community environments have on PA participation in children and youth.^{36, 37}

The strengths of this study include the use of a large and representative study sample, the use of an objective PA measure, and the statistical modelling approach that allowed us to accurately characterize the dose-response relation between PA, BP, and hypertension. The primary study limitation was the cross-sectional and observational nature, which prevents us from making causal inferences about the relation between PA and BP. Although objective in nature, PA accelerometers are not perfect measures of PA, and their main limitation is the inability to capture certain types of PA such as swimming and bicycling.¹⁴ Another issue with accelerometers is the discrepancy in thresholds used by different investigators to denote those minutes where the participants were physically active, as discussed in more details in the Methods section. Had different thresholds been employed in the present study, the slopes of the dose-response curves might have changed. In addition, we considered all minutes of physical activity, not just those minutes that occurred within bouts of at least a few minutes in length. Had we limited the physically active minutes to those that occurred in bouts, the total minutes of

physical activity in the study participants would have been reduced substantially, and the reduction in BP values or hypertension risk for a given increase in physical activity would have been larger. Finally, the slight differences in characteristics between the participants included in the analyses and the overall NHANES sample limits the generalizability of the results.

In summary, objective measures of PA were strongly related to hypertension but not to mean BP values. Meeting the guidelines of 60 min/d of moderate-to-vigorous intensity PA greatly reduces the likelihood of hypertension in the pediatric population. Unfortunately, few children and youth achieve this PA level.

ACKNOWLEDGEMENTS

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References

1. Twisk JW, Kemper HC, van Mechelen W. Tracking of activity and fitness and the relationship with cardiovascular disease risk factors. *Med Sci Sports Exerc* 2000;32(8):1455-61.
2. Twisk JW, Van Mechelen W, Kemper HC, Post GB. The relation between "long-term exposure" to lifestyle during youth and young adulthood and risk factors for cardiovascular disease at adult age. *J Adolesc Health* 1997;20(4):309-19.
3. Twisk JW, Kemper HC, van Mechelen W. The relationship between physical fitness and physical activity during adolescence and cardiovascular disease risk factors at adult age. The Amsterdam Growth and Health Longitudinal Study. *Int J Sports Med* 2002;23 Suppl 1:S8-14.
4. Twisk JW. Physical activity guidelines for children and adolescents: a critical review. *Sports Med* 2001;31(8):617-27.
5. Bao W, Threefoot SA, Srinivasan SR, Berenson GS. Essential hypertension predicted by tracking of elevated blood pressure from childhood to adulthood: the Bogalusa Heart Study. *Am J Hypertens* 1995;8(7):657-65.
6. Sun SS, Grave GD, Siervogel RM, Pickoff AA, Arslanian SS, Daniels SR. Systolic blood pressure in childhood predicts hypertension and metabolic syndrome later in life. *Pediatrics* 2007;119(2):237-46.
7. National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. *Pediatrics* 2004;114(2 Suppl 4th Report):555-76.

8. Williams CL, Hayman LL, Daniels SR, et al. Cardiovascular health in childhood: A statement for health professionals from the Committee on Atherosclerosis, Hypertension, and Obesity in the Young (AHOY) of the Council on Cardiovascular Disease in the Young, American Heart Association. *Circulation* 2002;106(1):143-60.
9. Kavey RE, Daniels SR, Lauer RM, Atkins DL, Hayman LL, Taubert K. American Heart Association guidelines for primary prevention of atherosclerotic cardiovascular disease beginning in childhood. *J Pediatr* 2003;142(4):368-72.
10. Strong WB, Malina RM, Blimkie CJ, et al. Evidence based physical activity for school-age youth. *J Pediatr* 2005;146(6):732-7.
11. Janssen I. Physical activity guidelines for children and youth. *Applied Physiology Nutrition and Metabolism* 2007;32(2E):S109-S21.
12. Gidding SS, Barton BA, Dorgan JA, et al. Higher self-reported physical activity is associated with lower systolic blood pressure: the Dietary Intervention Study in Childhood (DISC). *Pediatrics* 2006;118(6):2388-93.
13. Raitakari OT, Taimela S, Porkka KV, et al. Associations between physical activity and risk factors for coronary heart disease: the Cardiovascular Risk in Young Finns Study. *Med Sci Sports Exerc* 1997;29(8):1055-61.
14. Goran MI. Measurement issues related to studies of childhood obesity: assessment of body composition, body fat distribution, physical activity, and food intake. *Pediatrics* 1998;101(3 Pt 2):505-18.
15. Centers for Disease Control and Prevention (CDC). National Health and Nutrition Examination Survey Data. In: Department of Health and Human Services, Centers for Disease Control and Prevention, Hyattsville, MD: U.S.; 2003-2004.

16. Trost SG, Pate RR, Freedson PS, Sallis JF, Taylor WC. Using objective physical activity measures with youth: how many days of monitoring are needed? *Med Sci Sports Exerc* 2000;32(2):426-31.
17. Van Coevering P, Harnack L, Schmitz K, Fulton JE, Galuska DA, Gao S. Feasibility of using accelerometers to measure physical activity in young adolescents. *Med Sci Sports Exerc* 2005;37(5):867-71.
18. Masse LC, Fuemmeler BF, Anderson CB, et al. Accelerometer data reduction: a comparison of four reduction algorithms on select outcome variables. *Med Sci Sports Exerc* 2005;37(11 Suppl):S544-54.
19. Treuth MS, Schmitz K, Catellier DJ, et al. Defining accelerometer thresholds for activity intensities in adolescent girls. *Med Sci Sports Exerc* 2004;36(7):1259-66.
20. Guinhouya CB, Hubert H, Soubrier S, Vilhelm C, Lemdani M, Durocher A. Moderate-to-vigorous physical activity among children: discrepancies in accelerometry-based cut-off points. *Obesity (Silver Spring)* 2006;14(5):774-7.
21. Andersen LB, Harro M, Sardinha LB, et al. Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study). *Lancet* 2006;368(9532):299-304.
22. Puyau MR, Adolph AL, Vohra FA, Butte NF. Validation and calibration of physical activity monitors in children. *Obes Res* 2002;10(3):150-7.
23. Kuczmarski RJ, Ogden CL, Guo SS, et al. 2000 CDC Growth Charts for the United States: methods and development. *Vital Health Stat* 11 2002(246):1-190.
24. U.S. Department of Health and Human Services and National Center for Health Statistics. Documentation, Codebook, and Frequencies, Dietary Interview- Total Nutrient

Intakes (First Day). In: Department of Health and Human Services, Centers for Disease Control and Prevention, Hyattsville, MD: U.S.; 2007.

25. Bagnardi V, Zambon A, Quatto P, Corrao G. Flexible meta-regression functions for modeling aggregate dose-response data, with an application to alcohol and mortality. *Am J Epidemiol* 2004;159(11):1077-86.

26. Zhang J, Yu KF. What's the relative risk? A method of correcting the odds ratio in cohort studies of common outcomes. *Jama* 1998;280(19):1690-1.

27. Department of Health and Aging. National Physical Activity Guidelines for Australians. In: Government A, ed. Canberra: Canberra, Australia; 1999.

28. Biddle SJ, Sallis JF, Cavin N. Young and active? Young people and health-enhancing physical activity -- evidence and implications. In: Health Education Authority, ed. London: London, UK; 1999.

29. Brage S, Wedderkopp N, Ekelund U, et al. Objectively measured physical activity correlates with indices of insulin resistance in Danish children. The European Youth Heart Study (EYHS). *Int J Obes Relat Metab Disord* 2004;28(11):1503-8.

30. Kelley GA, Kelley KS, Tran ZV. The effects of exercise on resting blood pressure in children and adolescents: a meta-analysis of randomized controlled trials. *Prev Cardiol* 2003;6(1):8-16.

31. Fagard RH. Exercise characteristics and the blood pressure response to dynamic physical training. *Med Sci Sports Exerc* 2001;33(6 Suppl):S484-92; discussion S93-4.

32. Kelley GA, Kelley KS. Aerobic exercise and lipids and lipoproteins in children and adolescents: a meta-analysis of randomized controlled trials. *Atherosclerosis* 2007;191(2):447-53.

33. Kang HS, Gutin B, Barbeau P, et al. Physical training improves insulin resistance syndrome markers in obese adolescents. *Med Sci Sports Exerc* 2002;34(12):1920-7.
34. Health Canada and Canadian Society for Exercise Physiology. Canada's Physical Activity Guide to Healthy Active Living: Family Guide to Physical Activity for Youth 6-9 Years of Age. In. Ottawa, ON: Minister of Health; 2002.
35. Health Canada and the Canadian Society for Exercise Physiology. Canada's Physical Activity Guide to Healthy Active Living: Family Guide to Physical Activity for Youth 10-14 Years of Age. In. Ottawa, ON: Minister of Health; 2002.
36. Council on Sports Medicine and Fitness and Council on School Health. Active healthy living: prevention of childhood obesity through increased physical activity. *Pediatrics* 2006;117(5):1834-42.
37. Canadian Paediatric Society. Healthy active living for children and youth. *Paediatrics & Child Health* 2002;7(5):339-45.

Table 1: Descriptive characteristics of subjects (n=1170).

Characteristic	Proportion
Age	
8-10 years	22.5%
11-13 years	34.0%
14-17 years	43.5%
Gender	
Male	51.9%
Female	48.1%
Race/ethnicity	
Non-Hispanic white	25.6%
Non-Hispanic black	34.3%
Hispanic and Hispanic-Mexican	36.9%
Other	3.2%
Body Mass Index	
Normal weight	61.5%
At-risk for overweight	18.6%
Overweight	19.8%

Table 2: Distribution of study participants by minutes of physical activity.

Physical Activity (min/d)	Total PA		Moderate-to-vigorous PA	
	Males	Females	Males	Females
0 to <30	14.8%	36.9%	53.2%	85.1%
30 to <60	36.4%	44.9%	35.1%	13.5%
60 to <90	26.5%	14.6%	9.2%	0.9%
≥90	22.2%	3.6%	2.5%	0.5%

FIGURE CAPTIONS

Figure 1. Relation between: total physical activity and systolic blood pressure Z-scores (Panel A), moderate-to-vigorous physical activity and systolic blood pressure Z-scores (Panel B), total physical activity and diastolic blood pressure Z-scores (Panel C), and moderate-to-vigorous physical activity and diastolic BP Z-scores (Panel D). Solid lines represent the predicted relationship between physical activity and blood pressure Z-score for a 12 year old non-Hispanic white male, non-smoker, high poverty-to-income ration, consuming 2000 kcal/d, while the dashed lines represent the 95% confidence intervals.

Figure 2. Risk ratios for hypertension according to total physical activity (Panel A) and moderate-to-vigorous physical activity (Panel B). 1 minutes represents the referent value (risk ratio = 1.0) for physical activity. Solid lines represent the predicted relationships between physical activity and hypertension for a 12 year old non-Hispanic white male, non-smoker, high poverty-to-income ration, consuming 2000 kcal/d, while the dashed lines represent the 95% confidence intervals.

Figure 1

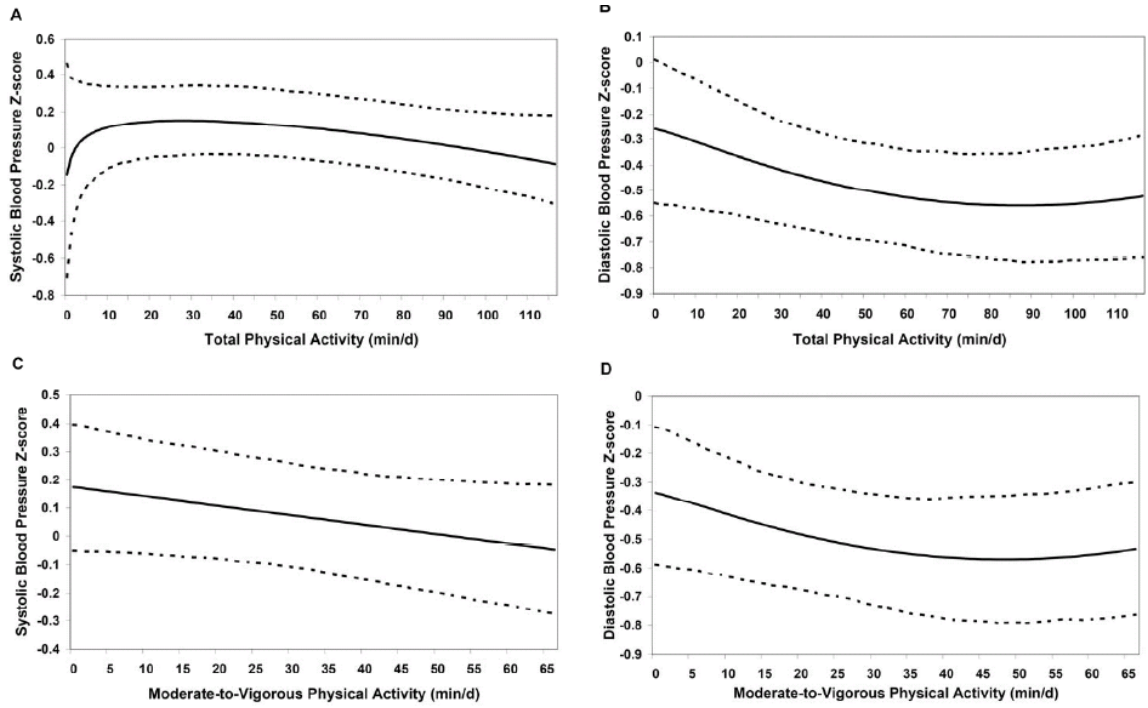
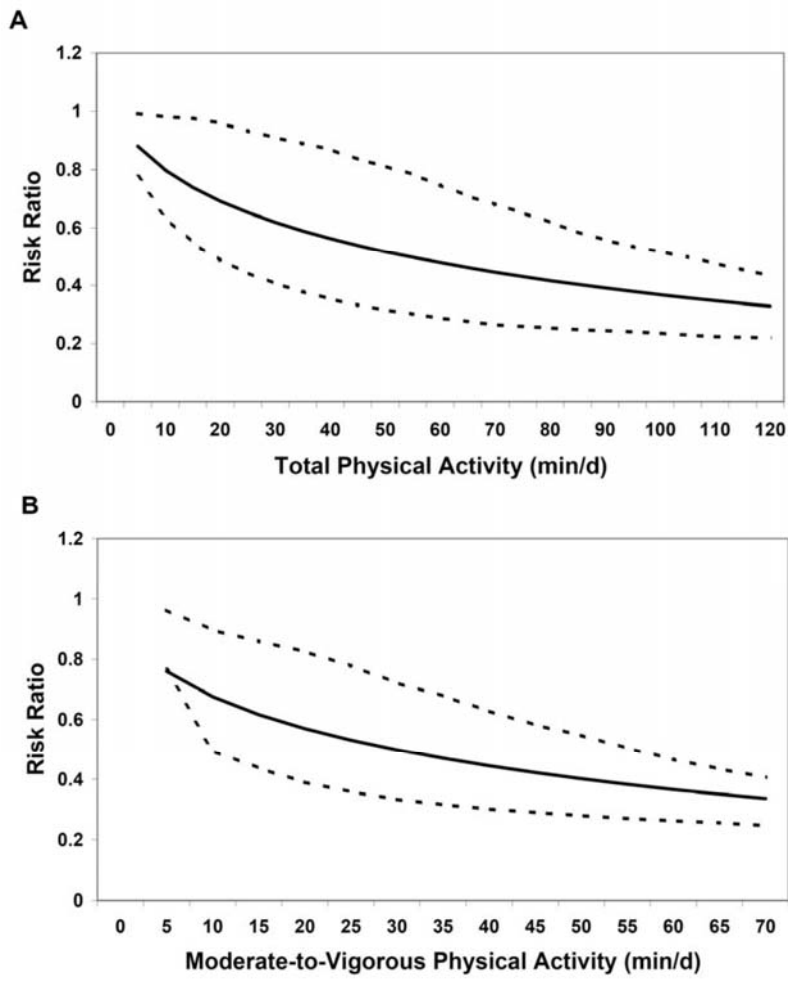


Figure 2



CHAPTER 4

Manuscript 2

Influence of Movement Intensity and Physical Activity on Adiposity in Youth.

This manuscript has been submitted for publication to the *International Journal of Pediatric Obesity* and has been presented in a format consistent with the journal requirements.

Guideline component: This manuscript explores the intensity component of the physical activity guidelines.

ABSTRACT

Objective: To explore the independent effects of physical activity intensity and incidental movement (movement while not engaging in physical activity) on total body and trunk fat in children and youth.

Methods: The sample consisted of 1165 youth aged 8-17 years from the 2003-2004 U.S. National Health and Nutrition Examination Survey, a representative cross-sectional survey. Physical activity was measured using Actigraph accelerometers over 7 days. Thresholds of 2000, 3000, and 5200 counts per minute were used to denote those minutes where participants were engaged in low, moderate, and vigorous intensity physical activity, respectively. Incidental movement was measured as mean counts per minute during waking hours below the 2000 threshold. Total body and trunk fat were measured using dual-energy X-ray absorptiometry; age- and sex-specific percentile scores were calculated.

Results: Bivariate analyses revealed an inverse relation between total, low, moderate and vigorous intensity physical activity with total body and trunk fat. After consideration of the total volume of physical activity in the multivariate analyses, moderate-to-vigorous intensity physical activity remained a significant predictor of total and trunk fat. Participants with the highest (top 12.5%) moderate-to-vigorous intensity activity values had total fat percentile scores that were 28 points lower than participants with the lowest (bottom 25%) values. Incidental movement was not negatively related to adiposity on its own or after controlling for physical activity.

Conclusion: These results support the public health recommendation that children and youth should participate in moderate-to-vigorous intensity physical activity.

INTRODUCTION

Childhood and youth obesity has surpassed epidemic proportions in many countries throughout the world and is a leading public health issue.¹⁻³ Physical activity is an integral part of the energy balance equation for maintenance of a healthy body composition. Although both cross-sectional and prospective observational studies provide consistent evidence of an inverse relation between physical activity with total⁴⁻¹⁰ and abdominal^{10, 11} adiposity, the possible influence of physical activity intensity on adiposity in youth remains unclear.

Some^{5, 9} but not all¹² studies report that the relation between physical activity and total adiposity is stronger for vigorous intensity activity than for moderate intensity activity. Similarly, others reported a significant relationship between moderate-to-vigorous intensity activity and adiposity after adjusting for total activity level.¹⁰ Nonetheless, reliance on poor measures of physical activity (e.g., self-report) and proxy measures of adiposity (e.g., body mass index), especially in population based research, has limited the ability of researchers to adequately determine the independent influence of physical activity intensity on adiposity. Determining whether or not the intensity of activity is independently related to obesity is crucial for the development of appropriate physical activity recommendations.

Recently, consideration has been given to the relation between obesity and incidental movement, defined as movement that falls below an intensity that would normally be considered as physical activity (e.g., fidgeting, walking around the home). Within active individuals only a small portion of the day is spent engaging in physical activity accounting for only a fraction of total daily energy expenditure.¹³ This suggest

that although low in intensity and sporadic in nature, the accumulated effect of incidental movement on energy expenditure over the course of the day could be quite meaningful, with potential long term effects on adiposity. Indeed, studies within adults have found that incidental movement is negatively related to obesity.¹⁴⁻¹⁶ However, because the few studies that have examined this relation are based on small sample sizes ($n \leq 20$) and did not consider the potential confounding effect of physical activity participation, the effect of incidental movement on adiposity remain speculative. Notwithstanding the lack of strong evidence in adults, this relation has not been examined in children and youth.

Despite the abundance of research examining the relation between physical activity and adiposity in children and youth, there are still unanswered questions about the appropriate intensity of activity required. Therefore, the purpose of this study was to explore the independent effects of physical activity intensity and incidental movement on total and trunk adiposity. This study employed precise and objective measures of both physical activity and adiposity to facilitate superior characterization of the physical activity-adiposity relation. A measure of trunk fat was included in addition to total fat since accumulation of fat in the abdominal and trunk region has been linked to an elevation in cardiovascular disease risk factors independent of total fat.^{17, 18}

METHODS

Study Sample

The study sample consisted of participants from the 2003-2004 National Health and Nutrition Examination Surveys (NHANES). NHANES is a representative cross-sectional survey of the U.S. population.¹⁹ NHANES participants were identified using a

complex, stratified, multistage, probability sampling design.¹⁹ The present study was limited to those aged 8 to 17 years who completed both the home and mobile exam center components of the survey required for the analysis. A more detailed description of the NHANES methodology is provided in Appendix B. Informed consent was obtained from all the parents and participants, and the 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.

Physical Activity and Incidental Movement

Physical activity and incidental movement were measured using Actigraph 7124 activity monitors (Actigraph, Ft. Walton Beach, FL). A detailed description of the use of activity monitors (accelerometers) for the assessment of physical activity is provided in Appendix D. Briefly, activity monitors can be used to objectively measure the duration and intensity of movement under free-living conditions.^{20,21} Monitors were provided to subjects during the mobile exam center exam, were programmed to start recording at midnight of the day following the exam, and recorded activity for the following 7 days. Participants were instructed to wear the monitor during waking hours except when it could get wet. Monitors were attached to elasticized fabric belts and worn on the right hip.

The Actigraph is a uniaxial monitor that measures the intensity of movement averaged over 1 minute sampling epochs. Data from each monitor was downloaded by the Centers for Disease Control and Prevention and checked for spurious data (e.g., biologically implausible values), which were subsequently removed. We did not remove additional spurious data; however, further data reduction was completed by the authors

before analyses were performed. Specifically, the current study only included subjects with at least 4 days of complete monitoring, including at least 1 weekend day. Four days of monitoring has a test-retest reliability of 0.7.²⁰ A day was considered complete if it included at least 10 hours of wear time.²⁰ Wear time was determined by filtering activity monitor data and deleting sections of more than 20 minutes of zero counts indicating non-wear time.²²

There is considerable discrepancy in the literature concerning the accelerometry threshold that should be used to classify physical activity intensity, and the proposed thresholds often vary by age and gender.²³ The thresholds used in this study were selected based on available evidence and best judgement of the authors. For each complete day of monitoring, thresholds of 2000 (walking ~4.0 km/h), 3000 (walking ~5.6 km/h), and 5200 (running ~8 km/h) counts per minute were used to denote those minutes where the participants were engaged in physical activity of at least a low, moderate, and vigorous intensity, respectively.²⁴ For each participant the minutes of physical activity at each of the intensities were summed, and then averaged over the number of days with available measures. Total activity was calculated as the sum of low, moderate, and vigorous activity. Moderate-to-vigorous activity was calculated as the sum of moderate and vigorous intensity activity. Incidental movement was measured as the mean counts per minute for all minutes below the low intensity physical activity threshold (activity <2000 counts per minute). Z-scores for incidental movement were calculated. Subjects were grouped into quartiles for each of the physical activity and incidental movement variables. The upper quartiles were further divided into two groups (low and high) due to the wide range in physical activity values.

Total and Trunk Fat

Dual energy X-ray absorptiometry (DXA) scans (Hologic QDR 4500A, Hologic Inc., Bedford, MA) were performed and used as an objective measure of body composition. Total and trunk fat mass (kg) were used as the outcome measures. The trunk includes gluteal and abdominal regions. Age, sex, and height adjusted z-scores were calculated for the two fat measures (log transformed to follow normal distribution), and then converted into percentile scores. The use of DXA for assessment of body composition in children and youth has been cross-calibrated in pig carcass models within the pediatric weight range (Pearson $r \geq 0.98$ between body fat measured by DXA and chemical analyses of pig carcasses).²⁵

Covariates

Covariates included sex, race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, and other), the poverty-to-income ratio (a measure of socioeconomic status), total caloric intake, and smoking status. For caloric intake, participants were queried and reported on type and amount of food and beverages consumed during the 24 hours prior to their examination. Results of the dietary recall were used to estimate total daily caloric intake (kcal/d).²⁶ Smoking status categories consisted of never smokers, ever smokers, and non-responders. Covariates were selected a priori based on their relation between both the exposures and outcomes of interest as reported in previous studies.

Statistical Analysis

All analyses were performed using Intercooled Stata 7 (Stata Corporation, College Station, TX, USA) to account for the complex design and sample weight of the NHANES survey. Pearson partial correlations were used to examine the relationship

between low, moderate, and vigorous intensity physical activity and incidental movement. A sample of a Pearson partial correlation output is presented in Appendix F. A square root transformation was used for the physical activity measures to convert them into normally distributed variables for the correlation analysis. Next, a series of linear regression models were used to explore the relation between the physical activity measures and incidental movement with total and trunk fat. Initially, bivariate analyses were performed which included each of the physical activity and incidental movement variables in separate models. We then ran a series of multivariate models that included two or more of the physical activity and incidental movement variables. The multivariate modeling strategy was designed to facilitate public health recommendations for physical activity. We wanted to determine whether higher intensities of physical activity predicted the adiposity measures above that predicted by the sum of the physical activity measures. In this way, if the higher intensity activities were not independent predictors, it would suggest the recommendations could focus on the volume of activity. Conversely, if the higher intensity activities predicted adiposity beyond the total volume, it would suggest that recommendations need to include a component on the intensity of the activity. The initial multivariate model (model 1) included quartiles of total physical activity and quintiles of moderate-to-vigorous intensity physical activity to determine if moderate-to-vigorous physical activity predicted the adiposity measures after controlling for the total volume. In model 2 vigorous physical activity was added in addition to the variables included in model 1. In model 3 incidental movement was added in addition to the variables included in model 2. Age, sex, ethnicity, the poverty-to-income ratio, smoking status, and total caloric intake were included as covariates in all regression models. All

logistic models were tested to ensure there were no issues of multicollinearity. A sample of linear regression output is presented in Appendix I.

RESULTS

The final sample included 1165 subjects aged 8 to 17 years with complete measures of physical activity, adiposity, and the study covariates. Demographic characteristics of subjects are presented in Table 1. By and large, subjects were physically inactive with only 6.9% participating in the recommended 60 daily minutes of moderate-to-vigorous intensity physical activity²⁷ and 69.0% accumulating 30 minutes/day or less of moderate-to-vigorous intensity physical activity. Most (62.6%) subjects accumulated 5 or fewer minutes of vigorous intensity physical activity per day. Incidental movement, low intensity, moderate intensity, and vigorous intensity physical activity were all significantly correlated with each other (Table 2). Additional descriptive information on the physical activity variables is contained within Table 3.

The bivariate analyses results revealed significant inverse dose-response relations between low intensity activity, moderate intensity activity, and vigorous intensity activity with total fat and trunk fat (Table 3). In other words, individuals participating in higher physical activity categories had lower total fat and trunk fat percentile scores. The β coefficients presented in Table 3 represent the predicted differences in body fat percentile scores between quintiles 2-4 with quintile 1. For instance, holding all covariates constant, a participant in the highest total physical activity category would be predicted to have a total fat that was 23.4 percentile units lower than a participant in the lowest total

physical activity category. Incidental movement was not related to total or trunk fat in the bivariate analysis (Table 3).

Multivariate analyses were performed to determine the independent relations between the various physical activity and incidental movement measures with total and trunk fat. After controlling for total physical activity (low + moderate + vigorous intensity), moderate-to-vigorous intensity physical activity remained a significant predictor of total fat (Model 1, Table 4) and trunk fat (Model 1, Table 5). The effect of increasing moderate-to-vigorous intensity physical activity after controlling for total activity is further illustrated in Figure 1. After controlling for total activity and the volume of moderate-to-vigorous physical activity, vigorous intensity physical activity was not a significant predictor of total fat (Model 2, Table 4) or trunk fat (Model 2, Table 5). Incidental movement was not significantly related to total fat (Model 3, Table 4) or trunk fat (Model 3, Table 5) after consideration of the various physical activity measures.

DISCUSSION

Within this large and diverse sample of youth, the relation between activity and adiposity was driven in large measure by the volume of moderate-to-vigorous intensity physical activity. In opposition to what has been suggested in the adult obesity literature, incidental movement was not negatively related to total or trunk fat. Similar observations were made for the total fat and trunk fat measures, which is not surprising considering that trunk fat accounted for ~40% of total fat.

Our finding that moderate-to-vigorous intensity physical activity predicted adiposity independent of the total volume of physical activity is in agreement with

previous observations from both cross-sectional¹⁰ and intervention studies.²⁸⁻³⁰ Within our study the volume of moderate-to-vigorous intensity physical activity was related to adiposity in a dose-response manner such that the most active of the study population had the lowest adiposity. Within the most active group of subjects (top 12.5%) the amount of moderate-to-vigorous intensity physical activity ranged from 50-142 minutes per day. Thus, the results from our study support the physical activity guidelines for school-aged children promoted by several organizations and countries,^{27, 31, 32} which recommend 60 or more minutes of moderate-to-vigorous physical activity on a daily basis.

After taking into consideration the volume of moderate-to-vigorous intensity physical activity, vigorous intensity physical activity per se did not explain any additional variance in total or trunk fat. Thus, while engaging in physical activity of at least a moderate intensity was important, no significant benefit was gained with vigorous intensity activity. This is an important observation given that many youngsters find it difficult and/or uncomfortable to participate in high level of vigorous intensity activity, which could negatively impact compliance rates.^{28, 33} Similarly, Gutin and colleagues reported that a vigorous intensity physical activity program did not produce more favorable changes in adiposity than a moderate intensity physical activity program in obese 13 to 16 year-olds when the two programs were matched for total energy expenditure.²⁸

Contrary to our findings and those of Gutin and colleagues,²⁸ several investigators report that vigorous, but not moderate, intensity physical activity is related to adiposity in children and youth.^{5, 7-9} The discrepancy between our findings and these later studies may reflect differences in the statistical analyses approaches employed. The multivariate

analyses used in our study was designed to determine whether higher intensities of physical activity predicted adiposity *beyond* the sum of all physical activity measures (e.g., independent variables consisted of total activity, moderate-to-vigorous activity, and vigorous activity). Conversely, these earlier studies included the volume of each specific physical activity intensity in their multivariate models (e.g., independent variables consisted of low intensity, moderate intensity, vigorous intensity). Thus, while vigorous intensity activity may have been a stronger adiposity predictor than moderate intensity activity in these studies, the difference in the predictive ability of these two physical activity intensities may have been small and clinically insignificant.

To our knowledge this is the first study to consider the influence of incidental movement on adiposity in children and youth. Within our study participants, only 6.2% of the time they were awake was spent engaging in physical activity, with the remaining 93.8% representing sedentary time where incidental movement was accumulated. Nonetheless, incidental movement was not negatively related to total or trunk fat. This finding was unexpected given the large body of evidence demonstrating an independent relation between sedentary behaviors, primarily in the form of television viewing, and obesity in youth.^{3, 34-36} Our finding supports the hypothesis that increased caloric consumption during television is driving the relation between television and obesity rather than a decrease in energy expenditure.³⁷ This is further supported by the findings from several studies noting a poor relation between the volume of screen time and physical activity.^{38, 39}

That we did not find an inverse relation between incidental movement and adiposity in the large sample of youth examined is inconsistent with previous

observations in adults.^{14,16} One of these studies reported that higher levels of incidental movement, determined indirectly by subtracting the other components of energy expenditure from total energy expenditure, was protective against weight gain induced by 8 weeks of overfeeding in a sample of 16 men and women.¹⁴ A second study reported that incidental movement, as measured by accelerometry over 10 days, was higher in a group of 10 sedentary lean adults in comparison to a group of 10 sedentary obese adults.¹⁶ The differences in incidental movement were maintained after the lean subjects were placed on an overfeeding diet and the obese subjects were placed on a weight loss diet.¹⁶ Several important methodological differences may account for the discrepancy in the findings between our pediatric study and the two adult studies. Most notably, the present study was observational and not experimental in design. However, it was based on a much larger and representative sample. Furthermore, the adult studies did not consider the physical activity level of the subjects, and in fact, one of them was limited to relatively sedentary individuals.¹⁶ Given the relation between incidental movement and physical activity noted in the present study, this suggests that the relation between incidental movement and adiposity in the adult studies may have been explained by the higher physical activity levels in individuals with higher incidental movement.

The strengths of this study include the use of a large and representative study sample, the use of precise measures of total and trunk adiposity, the use of an objective measure of physical activity, and the modeling approach employed which allowed us to tease apart the independent effects of the different intensities of movement on adiposity. The primary study limitation was the cross-sectional and observational nature, which prevents us from making causal inferences about the relation between physical activity

and adiposity. Although objective in nature, accelerometers are not perfect measures of physical activity, and their main limitation is the inability to capture certain types of physical activity such as swimming and bicycling.⁴⁰ Similarly, a single uniaxial accelerometer placed on the hip is not ideal as it would not capture all incidental movements (e.g., small upper body movements). Nonetheless, results from the aforementioned adult studies¹⁶ reported similar observations when incidental movement was measured by accelerometers or other techniques.

In conclusion, moderate-to-vigorous intensity physical activity predicted total and trunk adiposity beyond that predicted by the total volume of activity. These results support public health guidelines for physical activity that recommend children and youth participate in 60 or more minutes of moderate-to-vigorous intensity physical activity on a daily basis. Further studies in children and youth are needed to explore the relation between physical activity intensity and incidental movement with other health outcomes.

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References

1. Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM. Prevalence of overweight and obesity in the United States, 1999-2004. *JAMA* 2006;295(13):1549-55.
2. Kosti RI, Panagiotakos DB. The epidemic of obesity in children and adolescents in the world. *Cent Eur J Public Health* 2006;14(4):151-9.
3. Janssen I, Katzmarzyk PT, Boyce WF, et al. Comparison of overweight and obesity prevalence in school-aged youth from 34 countries and their relationships with physical activity and dietary patterns. *Obes Rev* 2005;6(2):123-32.
4. Eisenmann JC, Barteel RT, Wang MQ. Physical activity, TV viewing, and weight in U.S. youth: 1999 Youth Risk Behavior Survey. *Obes Res* 2002;10(5):379-85.
5. Gutin B, Yin Z, Humphries MC, Barbeau P. Relations of moderate and vigorous physical activity to fitness and fatness in adolescents. *Am J Clin Nutr* 2005;81(4):746-50.
6. Janssen I, Katzmarzyk PT, Boyce WF, King MA, Pickett W. Overweight and obesity in Canadian adolescents and their associations with dietary habits and physical activity patterns. *J Adolesc Health* 2004;35(5):360-7.
7. Dencker M, Thorsson O, Karlsson MK, et al. Daily physical activity related to body fat in children aged 8-11 years. *J Pediatr* 2006;149(1):38-42.
8. Patrick K, Norman GJ, Calfas KJ, et al. Diet, physical activity, and sedentary behaviors as risk factors for overweight in adolescence. *Arch Pediatr Adolesc Med* 2004;158(4):385-90.

9. Ruiz JR, Rizzo NS, Hurtig-Wennlof A, Ortega FB, Warnberg J, Sjostrom M. Relations of total physical activity and intensity to fitness and fatness in children: the European Youth Heart Study. *Am J Clin Nutr* 2006;84(2):299-303.
10. Ness AR, Leary SD, Mattocks C, et al. Objectively measured physical activity and fat mass in a large cohort of children. *Plos Medicine* 2007;4(3):476-84.
11. Andersen LB, Harro M, Sardinha LB, et al. Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study). *Lancet* 2006;368(9532):299-304.
12. Rizzo NS, Ruiz JR, Hurtig-Wennlof A, Ortega FB, Sjostrom M. Relationship of physical activity, fitness, and fatness with clustered metabolic risk in children and adolescents: the European youth heart study. *J Pediatr* 2007;150(4):388-94.
13. Goran MI, Treuth MS. Energy expenditure, physical activity, and obesity in children. *Pediatr Clin North Am* 2001;48(4):931-53.
14. Levine JA, Eberhardt NL, Jensen MD. Role of nonexercise activity thermogenesis in resistance to fat gain in humans. *Science* 1999;283(5399):212-4.
15. Hamilton MT, Hamilton DG, Zderic TW. Role of low energy expenditure and sitting in obesity, metabolic syndrome, type 2 diabetes, and cardiovascular disease. *Diabetes* 2007;56(11):2655-67.
16. Levine JA, Lanningham-Foster LM, McCrady SK, et al. Interindividual variation in posture allocation: possible role in human obesity. *Science* 2005;307(5709):584-6.
17. Caprio S, Hyman LD, McCarthy S, Lange R, Bronson M, Tamborlane WV. Fat distribution and cardiovascular risk factors in obese adolescent girls: importance of the intraabdominal fat depot. *Am J Clin Nutr* 1996;64(1):12-7.

18. Teixeira PJ, Sardinha LB, Going SB, Lohman TG. Total and regional fat and serum cardiovascular disease risk factors in lean and obese children and adolescents. *Obes Res* 2001;9(8):432-42.
19. Centers for Disease Control and Prevention (CDC). National Health and Nutrition Examination Survey Data. In: Department of Health and Human Services, Centers for Disease Control and Prevention, Hyattsville, MD: U.S.; 2003-2004.
20. Trost SG, Pate RR, Freedson PS, Sallis JF, Taylor WC. Using objective physical activity measures with youth: how many days of monitoring are needed? *Med Sci Sports Exerc* 2000;32(2):426-31.
21. Van Coevering P, Harnack L, Schmitz K, Fulton JE, Galuska DA, Gao S. Feasibility of using accelerometers to measure physical activity in young adolescents. *Med Sci Sports Exerc* 2005;37(5):867-71.
22. Masse LC, Fuemmeler BF, Anderson CB, et al. Accelerometer data reduction: a comparison of four reduction algorithms on select outcome variables. *Med Sci Sports Exerc* 2005;37(11 Suppl):S544-54.
23. Guinhouya CB, Hubert H, Soubrier S, Vilhelm C, Lemdani M, Durocher A. Moderate-to-vigorous physical activity among children: discrepancies in accelerometry-based cut-off points. *Obesity (Silver Spring)* 2006;14(5):774-7.
24. Treuth MS, Schmitz K, Catellier DJ, et al. Defining accelerometer thresholds for activity intensities in adolescent girls. *Med Sci Sports Exerc* 2004;36(7):1259-66.
25. Pintauro SJ, Nagy TR, Duthie CM, Goran MI. Cross-calibration of fat and lean measurements by dual-energy X-ray absorptiometry to pig carcass analysis in the pediatric body weight range. *Am J Clin Nutr* 1996;63(3):293-8.

26. U.S. Department of Health and Human Services and National Center for Health Statistics. Documentation, Codebook, and Frequencies, Dietary Interview- Total Nutrient Intakes (First Day). In: Department of Health and Human Services, Centers for Disease Control and Prevention, Hyattsville, MD: U.S.; 2007.
27. Strong WB, Malina RM, Blimkie CJ, et al. Evidence based physical activity for school-age youth. *J Pediatr* 2005;146(6):732-7.
28. Gutin B, Barbeau P, Owens S, et al. Effects of exercise intensity on cardiovascular fitness, total body composition, and visceral adiposity of obese adolescents. *Am J Clin Nutr* 2002;75(5):818-26.
29. LeMura LM, Maziekas MT. Factors that alter body fat, body mass, and fat-free mass in pediatric obesity. *Med Sci Sports Exerc* 2002;34(3):487-96.
30. Owens S, Gutin B, Allison J, et al. Effect of physical training on total and visceral fat in obese children. *Med Sci Sports Exerc* 1999;31(1):143-8.
31. Health Canada and Canadian Society for Exercise Physiology. Canada's Physical Activity Guide to Healthy Active Living: Family Guide to Physical Activity for Youth 6-9 Years of Age. In. Ottawa, ON: Minister of Health; 2002.
32. Health Canada and the Canadian Society for Exercise Physiology. Canada's Physical Activity Guide to Healthy Active Living: Family Guide to Physical Activity for Youth 10-14 Years of Age. In. Ottawa, ON: Minister of Health; 2002.
33. Epstein LH, Coleman KJ, Myers MD. Exercise in treating obesity in children and adolescents. *Med Sci Sports Exerc* 1996;28(4):428-35.

34. Ekelund U, Brage S, Froberg K, et al. TV viewing and physical activity are independently associated with metabolic risk in children: the European Youth Heart Study. *PLoS Med* 2006;3(12):e488.
35. Hancox RJ, Milne BJ, Poulton R. Association between child and adolescent television viewing and adult health: a longitudinal birth cohort study. *Lancet* 2004;364(9430):257-62.
36. Dietz WH, Jr., Gortmaker SL. Do we fatten our children at the television set? Obesity and television viewing in children and adolescents. *Pediatrics* 1985;75(5):807-12.
37. Robinson TN. Television viewing and childhood obesity. *Pediatric Clinics of North America* 2001;48(4):1017.
38. Andersen RE, Crespo CJ, Bartlett SJ, Cheskin LJ, Pratt M. Relationship of physical activity and television watching with body weight and level of fatness among children: results from the Third National Health and Nutrition Examination Survey. *JAMA* 1998;279(12):938-42.
39. Gordon-Larsen P, McMurray RG, Popkin BM. Determinants of adolescent physical activity and inactivity patterns. *Pediatrics* 2000;105(6):E83.
40. Goran MI. Measurement issues related to studies of childhood obesity: assessment of body composition, body fat distribution, physical activity, and food intake. *Pediatrics* 1998;101(3 Pt 2):505-18.

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Table 1. Subject characteristics.

	Total	Males	Females
	(n = 1165)	(n=608)	(n=557)
Age (years)	12.9 ± 2.7	13.0 ± 2.7	12.8 ± 2.7
Race/Ethnicity			
Non-Hispanic White	26.1%	25.3%	26.9%
Non-Hispanic Black	34.1%	37.0%	30.9%
Hispanic	36.6%	34.7%	38.6%
Other	3.3%	3.0%	3.6%
Total Body Fat (kg)	16.9 ± 9.6	15.4 ± 9.2	18.5 ± 9.9
Trunk Fat (kg)	6.7 ± 4.7	6.0 ± 4.4	7.4 ± 4.9
Incidental Movement (cmp)	270.9 ± 88.5	282.1 ± 88.6	258.6 ± 86.8
Low Intensity PA (min/d)	27.2 ± 14.2	31.3 ± 15.1	22.7 ± 11.6
Moderate Intensity PA (min/d)	19.9 ± 14.9	25.5 ± 16.4	13.7 ± 10.0
Vigorous Intensity PA (min/d)	6.0 ± 7.6	8.2 ± 8.5	3.7 ± 5.6
Caloric Intake (kcal/d)	2241 ± 978	2452 ± 1055	2011 ± 829

Data presented as mean ± SD for continuous variables and prevalence (%) for categorical variables. cmp = counts per minute, PA = physical activity.

Table 2. Partial correlations (r values) between physical activity and incidental movement measures.

	Incidental Movement	Low Intensity PA	Moderate Intensity PA	Vigorous Intensity PA
Incidental Movement	1.00	0.70	0.45	0.28
Low Intensity PA		1.00	0.80	0.48
Moderate Intensity PA			1.00	0.67
Vigorous Intensity PA				1.00

PA = physical activity.

All correlations were significant ($P < 0.0001$). Correlations adjusted for sex, age, race/ethnicity, caloric intake (kcal/d), the poverty-to-income ratio and smoking status.

Table 3. Bivariate relations between physical activity and incidental movement measures with total and trunk fat.

	Quartile	Range ^e	Total Fat Percentile	Trunk Fat Percentile
			β (s.e.) ^d	β (s.e.) ^d
Total Physical Activity	1	0.0 – 29.6	(referent)	(referent)
	2	29.7 – 47.2	-13.15 (4.47) ^b	-13.45 (4.72) ^a
	3	47.3 – 70.1	-14.15 (3.06) ^c	-13.96 (3.06) ^c
	4	70.2 – 252.7	-23.42 (4.15) ^c	-23.24 (4.40) ^c
		$p_{\text{trend}} < 0.001$	$p_{\text{trend}} < 0.001$	
Incidental Movement	1	0.0 – 210.1	(referent)	(referent)
	2	210.1 – 263.9	0.59 (2.82)	0.93 (2.72)
	3	264.0 – 326.7	-4.13 (3.34)	-4.24 (3.28)
	4	327.2 – 580.5	-5.24 (3.22)	-4.68 (3.18)
		$p_{\text{trend}} = 0.070$	$p_{\text{trend}} = 0.090$	
Low Intensity Physical Activity	1	0.0-17.2	(referent)	(referent)
	2	17.3-25.0	-8.25 (3.63) ^a	-8.48 (3.60) ^a
	3	25.0-35.2	-10.65 (2.89) ^b	-10.33 (3.16) ^b
	4 (low)	35.2-43.5	-15.54 (5.57) ^a	-15.38 (5.40) ^a
	4 (high)	43.6-110.5	-18.62 (3.77) ^c	-18.43 (3.94) ^c
		$p_{\text{trend}} < 0.001$	$p_{\text{trend}} < 0.001$	
Moderate Intensity Physical Activity	1	0.0-9.3	(referent)	(referent)
	2	9.3-16.3	-10.98 (2.71) ^b	-10.72 (3.21) ^b
	3	16.3-26.8	-18.42 (3.67) ^c	-18.32 (3.80) ^c
	4 (low)	26.8-37.2	-19.46 (3.44) ^c	-19.30 (3.40) ^c
	4 (high)	37.3-116.2	-27.75 (4.25) ^c	-25.94 (4.51) ^c
		$p_{\text{trend}} < 0.001$	$p_{\text{trend}} < 0.001$	
Vigorous Intensity Physical Activity	1	0.0 – 1.1	(referent)	(referent)
	2	1.2 – 3.3	-9.83 (3.93) ^a	-9.88 (3.86) ^a
	3	3.4 – 7.9	-15.93 (4.05) ^b	-15.35 (4.11) ^b
	4 (low)	8.0 – 13.0	-20.32 (4.61) ^b	-19.69 (4.79) ^b
	4 (high)	13.1 – 58.2	-22.71 (3.83) ^c	-22.55 (3.86) ^c
		$p_{\text{trend}} < 0.001$	$p_{\text{trend}} < 0.001$	

^a $p < 0.05$, ^b $p < 0.01$, ^c $p < 0.001$ vs. referent group. ^dStandard error of the parameter estimate.

^eRanges are minutes per day for physical activity, and mean counts per minute for incidental movement.

All analyses adjusted for sex, age, race/ethnicity, caloric intake (kcal/d), the poverty-to-income ratio and smoking status.

Table 4. Multivariate relation between physical activity and incidental movement measures with total fat percentile scores.

Activity Type	Quartile	Model 1 β (s.e.)	Model 2 β (s.e.)	Model 3 β (s.e.)
Total Physical Activity	1	0 (referent)	(referent)	(referent)
	2	-4.83 (5.00)	-4.27 (4.64)	-6.12 (4.28)
	3	0.70 (4.18)	1.01 (3.94)	-2.55 (4.38)
	4	-0.10 (6.61)	0.44 (6.15)	-3.92 (6.51)
		$p_{\text{trend}}=0.905$	$p_{\text{trend}}=0.883$	$p_{\text{trend}}=0.389$
Moderate-to-Vigorous Physical Activity	1	0 (referent)	(referent)	(referent)
	2	-9.51 (3.59) ^a	-7.44 (3.06) ^a	-6.53 (2.76) ^a
	3	-16.77 (4.30) ^b	-13.73 (3.98) ^b	-11.89 (4.01) ^a
	4 (low)	-24.41 (5.52) ^c	-21.60 (6.76) ^b	-19.20 (6.68) ^a
	4 (high)	-28.90 (5.12) ^c	-26.83 (7.46) ^b	-24.33 (6.76) ^b
		$p_{\text{trend}}<0.001$	$p_{\text{trend}}=0.006$	$p_{\text{trend}}=0.007$
Vigorous Physical Activity	1		(referent)	(referent)
	2		-3.90 (2.88)	-4.14 (2.90)
	3		-5.18 (4.27)	-5.48 (4.34)
	4 (low)		-4.76 (4.87)	-5.10 (5.06)
	4 (high)		-3.26 (6.68)	-3.61 (6.71)
		$p_{\text{trend}}=0.520$	$p_{\text{trend}}=0.505$	
Incidental Movement	1			(referent)
	2			4.93 (2.76)
	3			2.20 (3.22)
	4			5.58 (2.97)
				$p_{\text{trend}}=0.160$

^a $p<0.05$ ^b $p<0.01$ ^c $p<0.001$ vs. referent group. ^ds.e. Standard error of the parameter estimate. All models adjusted for sex, age, race/ethnicity, caloric intake (kcal/d), the poverty-to-income ratio and smoking status.

Table 5. Multivariate relation between physical activity and incidental movement measures with trunk fat percentile scores.

Activity Type	Quartile	Model 1	Model 2	Model 3
		β (s.e.)	β (s.e.)	β (s.e.)
Total Physical Activity	1	0 (referent)	(referent)	(referent)
	2	-5.55 (5.20)	-5.01 (4.84)	-7.10 (4.58)
	3	-0.85 (4.51)	-0.50 (4.20)	-4.70 (4.56)
	4	-2.52 (6.89)	-2.17 (6.43)	-7.43 (6.92)
		$p_{\text{trend}}=0.629$	$p_{\text{trend}}=0.608$	$p_{\text{trend}}=0.211$
Moderate-to-Vigorous Physical Activity	1	0 (referent)	(referent)	(referent)
	2	-9.05 (4.26)	-7.03 (3.65)	-6.00 (3.38)
	3	-14.73 (4.84) ^b	-11.73 (4.50) ^a	-9.59 (4.35) ^a
	4 (low)	-21.78 (5.73) ^b	-18.58 (7.23) ^a	-15.73 (6.99) ^a
	4 (high)	-25.84 (5.90) ^b	-22.93 (8.21) ^a	-19.95 (7.38) ^a
		$p_{\text{trend}}<0.001$	$p_{\text{trend}}=0.027$	$p_{\text{trend}}=0.034$
Vigorous Physical Activity	1		(referent)	(referent)
	2		-3.88 (2.68)	-4.17 (2.74)
	3		-4.92 (4.47)	-5.25 (4.55)
	4 (low)		-4.85 (5.14)	-5.21 (5.34)
	4 (high)		-4.28 (7.17)	-4.65 (7.15)
			$p_{\text{trend}}=0.497$	$p_{\text{trend}}=0.481$
Incidental Movement	1			(referent)
	2			5.45 (2.73)
	3			2.38 (3.17)
	4			6.62 (3.17)
				$p_{\text{trend}}=0.123$

^a $p<0.05$ ^b $p<0.01$ ^c $p<0.001$ vs. referent group.

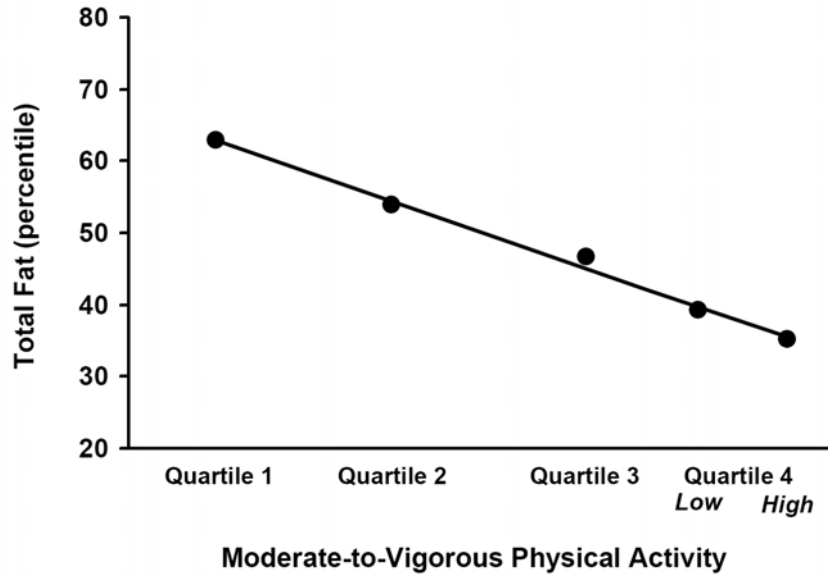
^ds.e. Standard error of the parameter estimate.

All models adjusted for sex, age, race/ethnicity, caloric intake (kcal/d), the poverty-to-income ratio and smoking status.

FIGURE CAPTION

Figure 1. Total fat percentile score according to the level of moderate-to-vigorous intensity physical activity level for a 13 year old non-Hispanic white male with a caloric intake of 2000 kcal/d, a poverty-to-income ratio at the group mean, non-smoker, and a total physical activity level within the second quartile. Note that this figure does not represent the data for an individual patient/subject, but rather than *predicted* value for someone with the aforementioned characteristics.

Figure 1



CHAPTER 5

Manuscript 3

*Relation between sporadic and bouts of physical activity
with overweight and obesity in youth*

This manuscript has been submitted with revisions for publication to the *American Journal of Preventive Medicine* and has been presented in a format consistent with the journal requirements.

Guideline component: This manuscript explores whether accumulating physical activity in bouts, as recommended in the Canadian Physical Activity guidelines for youth, confers any benefits beyond the total volume of physical activity.

ABSTRACT

Background. It is unknown whether bouts of physical activity (PA) confer benefits beyond the total volume of PA in youth.

Methods. The sample included 2498 youth (8-17 years) from the 2003-2006 National Health and Nutrition Examination Surveys. Sporadic (<5 min), short bouts (5-9 min), and medium-to-long bouts (≥ 10 min) of PA were measured over 7 days using Actigraph accelerometers. Body mass index was used to classify participants as normal weight or overweight. Logistic regression was used to predict the relative odds of overweight according to total and bouts of PA.

Results. After controlling for the volume of PA, individuals in the highest quartile for total bouts of PA (short + medium-to-long) were only 0.50 (0.27-0.84) times as likely to be overweight compared to the lowest quartile. After controlling for the volume of PA and the amount accumulated in short bouts, individuals in the highest quartile for medium-to-long bouts of PA were only 0.66 (0.43-0.96) times as likely to be overweight compared to the lowest quartile.

Conclusions. PA accumulated in bouts conferred benefits on adiposity status above those of the volume of PA in this large sample of youth.

INTRODUCTION

Physical activity in children and youth, especially younger children, tends to be somewhat sporadic in nature rather than the structured and continuous physical activity that is typically observed in adults.¹ For instance, while an active adult who participates in 45 minutes of daily physical activity may accumulate this in a single 45 minutes session, a child who participates in 45 minutes of daily physical activity would tend to do so in a less programmatic manner by accumulating a few minutes of play here and there over the course of the day.

It is unknown if this sporadic physical activity confers similar health benefits as physical activity accrued in bouts. Deciphering whether physical activity accrued in bouts offers additional health benefits has important public health implications with respect to the promotion of physical activity in children and youth. Current public health guidelines recommend that young people accumulate at least 60 minutes of moderate-to-vigorous intensity physical activity on a daily basis.^{2,3} Stipulations have not been made regarding how the minutes should be accumulated.^{2,3} If physical activity accrued in bouts has health benefits beyond the total volume of physical activity, the message for children and youth may need to be changed from “accumulate at least 60 minutes of daily physical activity” to “accumulate at least 60 minutes of daily physical activity in bouts of at least 5 minutes in duration”

The primary purpose of this study was to explore whether physical activity accrued in bouts predicts overweight and obesity in youth above and beyond what is predicted by the total volume of physical activity. Short (5 to 9 minutes) and medium-to-long (≥ 10 minutes) length bouts of physical activity were considered.

METHODS

Study Sample

The study sample consisted of participants from the 2003-2004 and 2005-2006 National Health and Nutrition Examination Surveys (NHANES). NHANES is a representative cross-sectional survey of the U.S. population, and multiple rounds of the survey can be combined as done here.⁴ NHANES participants were identified using a complex, stratified, multistage, probability sampling design.⁴ The present study was limited to those aged 8 to 17 years who completed both the home and mobile exam center (MEC) components of the survey required for the analysis. Informed consent was obtained from parents and participants, and the protocol was approved by the National Center for Health Statistics. A more detailed description of the NHANES methodology is provided in Appendix B. The secondary analysis presented here was approved by the Queen's University Health Sciences Research Ethics Board.

Physical Activity (Exposure)

Physical activity was measured using Actigraph 7124 activity monitors (Actigraph, Ft. Walton Beach, FL). A more detailed description of the use of activity monitors for the assessment of physical activity is provided in Appendix D. Briefly, activity monitors can be used to objectively measure the duration and intensity of physical activity under free-living conditions.^{5,6} Monitors were provided to subjects during the MEC exam, were programmed to start recording at midnight of the day following the exam, and recorded activity for the following 7 days. Participants were instructed to wear the monitor during waking hours except when it could get wet. Monitors were attached to elasticized fabric belts and worn on the right hip.

The Actigraph is a uniaxial monitor that measures the intensity of movement averaged over 1 minute sampling epochs. Data from each monitor was downloaded by the Centers for Disease Control and Prevention and checked for spurious data (e.g., biologically implausible values), which were subsequently removed. We did not remove additional spurious data; however, further data reduction was completed by the authors before analyses were performed. Specifically, to help ensure that the physical activity monitor data was reliable, the current study only included subjects with at least 4 days of complete monitoring, including at least 1 weekend day. Four days of monitoring has a test-retest reliability of 0.7.⁵ A day was considered complete if it included at least 10 hours of wear time.⁵ Wear time was determined by filtering activity monitor data and deleting sections of more than 20 minutes of zero counts indicating non-wear time.⁷

A threshold of 3000 (equivalent to walking ~5.6 km/h) counts per minute was used to denote those minutes where the participants were engaged in moderate-to-vigorous intensity physical activity.⁸ There is considerable discrepancy in the literature concerning the accelerometry threshold that should be used to classify physical activity intensity.⁹ The thresholds used in this study were selected based on available evidence and best judgement of the authors. Although the thresholds used here were developed from a study conducted entirely in adolescent females, similar thresholds have been used for males and females^{10, 11} and in youth ranging in age from 6 to 16 years.¹¹ Thresholds were based on metabolic equivalents during activities of daily living (e.g., threshold for moderate-to-vigorous physical activity based on counts per minute for activity of 3 metabolic equivalents).

For each complete day of monitoring, data was filtered to determine the number of minutes spent in sporadic activity (<5 minutes), short bouts (5-9 minute), and medium-to-long bouts (≥ 10 minute) of moderate-to-vigorous intensity physical activity. These bout lengths were selected in part based upon examination of the physical activity data in the study population (e.g., few participants had sessions ≥ 20 minutes) and in part to represent durations of physical activity that may be suitable for physical activity recommendations. Participants were required to spend at least 80% of the bout above the threshold for the bout to be counted (e.g., for a 5 minute bout, 4 minutes would have to be above 3000 counts per minute). 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). Total physical activity represents the sum of the minutes spent in sporadic, short bouts, and medium-to-long bouts of physical activity. Note that for many participants the average daily minutes spent in bouts fell below the minimum bout duration. This is a reflection of the fact that the average time spent in bouts per day was calculated using the daily average over the week long measurement period and bouts of PA did not occur each day for all participants.

Overweight (Outcome)

Height and weight were measured to the nearest 0.1 cm and 0.1 kg, respectively, and used to calculate the body mass index (BMI, kg/m^2). Participants were classified as normal weight, overweight, or obese according to the International Obesity Task Force age- and sex-specific BMI cut-points. The cut-points for overweight and obesity corresponds BMI values of $25 \text{ kg}/\text{m}^2$ and $30 \text{ kg}/\text{m}^2$, respectively, at 18.0 years of age.¹²

In this study, we predicted whether the participants were overweight or obese, and have used the term overweight to refer to the combined overweight and obese groups.

Covariates

Information on sex and race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, and other) were obtained. The poverty-to-income ratio, which is a measure of the ratio between family income and the family poverty threshold based on family size and composition, was used as a measure of socioeconomic status. For caloric intake, participants were queried and reported on type and amount of food and beverages consumed during the 24 hours prior to their examination. Results of the dietary recall were used to estimate total daily caloric intake (kcal/d).¹³ Smoking status categories consisted of never smokers, ever smokers, and non-responders. Covariates were selected a priori based on their relation between both the exposures and outcomes of interest as reported in previous studies.

Statistical Analyses

For the total, sporadic, and short bout physical activity measures participants were grouped into quartiles; the lowest quartile was used as the reference group for all analyses. For the medium-to-long bout physical activity measure, youth who did not have any bouts were used as the referent group (37.2% of study sample), and the remaining youth were split into three equal categories (low, moderate, and high).

Spearman rank correlations were used to examine the relationship between the different physical activity measures, each of which was highly skewed. A sample of Spearman correlations is presented in Appendix G. Logistic regression was used to examine the relative odds of overweight according to groups of total physical activity,

sporadic physical activity, and physical activity accumulated in bouts. A sample of logistic regression output is present in Appendix J. Initially, bivariate logistic models were run to examine the relation between each physical activity measure and overweight. Subsequently, a series of multivariate logistic regression models were used to explore whether bouts of physical activity predicted the odds of overweight beyond that predicted by the total volume of physical activity. The initial multivariate regression model (Model 1) included quartiles of total physical activity and quartiles of physical activity accrued in bouts (short bouts + medium-to-long bouts). To explore the possible independent influence of bout length, a second multivariate regression model (Model 2) included quartiles of total physical activity, quartiles of short bouts, and categories of medium-to-long bouts of physical activity.

To further explore the potential influence of bout length on overweight, participants were divided into one of four groups based on median values for total physical activity and the proportion of total physical activity spent in bouts. The four groups were low total physical activity with a low proportion of PA time in bouts (low total/low bouts), low total physical activity with a high proportion of bouts (low total/high bouts), high total physical activity with a low proportion of bouts (high total/low bouts), and high total physical activity with a high proportion of bouts (high total/high bouts). Logistic regression analyses were used to examine the likelihood of being overweight across groups.

Because overweight/obesity was not a rare outcome in the study sample, the odds ratios (OR) obtained from logistic regression analyses do not approximate relative risk.¹⁴

Therefore, risk ratios (RR) were derived by adjusting OR by the proportion of the outcome in the referent groups (P_0) as follows: $RR=OR/((1-P_0) + (P_0 \times OR))$.¹⁴

Sex, age, race/ethnicity, smoking status, caloric intake, and the poverty-to-income ratio were included as covariates in all of the logistic regression analyses. Analyses were performed using Intercooled Stata 7.0 (Stata Corporation, College Station, TX, USA) to account for the complex design and sample weights of the NHANES survey.

RESULTS

Descriptive characteristics of subjects are presented in Table 1. Complete measures on physical activity and adiposity were available for 2498 participants aged 8 to 17 years. Sporadic physical activity accounted for 66.0% (60.4% in males, 71.7% in females) of the time spent engaging in moderate-to-vigorous physical activity (Table 1). 82.2% of youth engaged in at least one short bout (5-9 minutes) of physical activity on the average day and 62.8% participated in at least one medium-to-long bout (≥ 10 minutes) on the average day.

The correlations between the total, sporadic, short bout, and medium-to-long bout physical activity measures are provided in Table 2. Without exception, the four physical activity measures were significantly correlated with each other, with correlations ranging from 0.43 to 0.78. Total physical activity was correlated to a similar order of magnitude with the amount of physical activity performed sporadically ($r=0.78$) as well as in short ($r=0.75$) and medium-to-long ($r=0.75$) bouts.

Results of the bivariate logistic regression analyses are presented in Table 3. Without exception, the total, sporadic, short bout, and medium-to-long bout physical

activity measures were related to the likelihood of overweight in an inverse, dose-response manner ($p_{\text{trend}} < 0.05$). The most active total physical activity quartile was only 33% as likely to be overweight by comparison to the least active quartile. Similar observations were made for the individual component measures that comprised total physical activity.

A series of multivariate logistic regression models were used to examine whether physical activity accrued in bouts predicted overweight after accounting for the total volume of physical activity (Table 4). After consideration of the total volume of physical activity, the inclusion of total time spent in bouts of physical activity (short + medium-to-long) was significantly ($P_{\text{trend}} < 0.05$) inversely related to the risk ratio of overweight (Model 1). For example, those in the highest quartile for the total bouts measure were only 50% as likely to be overweight by comparison to those in the lowest quartile for the total bouts measure. After consideration of the total volume of physical activity and the amount of physical activity accrued in short bouts, the time spent in medium-to-long bouts of physical activity was significantly ($P_{\text{trend}} < 0.05$) inversely related to the risk ratio of overweight in a dose-response manner (Model 2).

In a final set of analyses we compared differences in overweight between: 1) youth participating in low total activity and low proportion of bouts versus low total activity and a high proportion of bouts (low-high), and 2) youth participating in high total activity and a low proportion of bouts (high-low) versus high total activity and a high proportion of bouts (high-high). In logistic regression analysis, the likelihood of overweight was not significantly lower for youth in the low-high group (risk ratio = 0.93, 95% confidence interval = 0.71-1.16) compared to those in the low-low group.

Conversely, youth in the high-high category were significantly less likely to be overweight (0.48, 0.37-0.61) compared to those in the high-low group. The prevalence of overweight was 46.6%, 40.8%, 33.7% and 25.4% in the low-low, low-high, high-low and high-high groups, respectively.

DISCUSSION

The key finding of this study was that physical activity accrued in bouts predicted adiposity status independent of the total volume of physical activity. Furthermore, longer bouts of physical activity had an effect on overweight above and beyond short bouts. Given that the magnitude of effect for bouts of physical activity on the likelihood of being overweight was large, and that there were clear dose-response patterns for these relations, these are compelling findings that speak to the importance of bouts of physical activity for school-aged youth. These novel findings have an important public health message and imply that physical activity recommendations for body weight management in the pediatric population should include a component recommending that at least some of the daily physical activity be accumulated in bouts. Given that the majority (66%) of the total physical activity within this study sample was accumulate in a sporadic manner, messages about performing physical activity over longer durations may be warranted for a large segment of the pediatric population.

The inverse relation between the volume of physical activity and overweight in youth observed in the present study is consistent with the literature.¹⁵⁻¹⁸ Intuitively, one would assume that with more physical activity, the more energy expended, and the lower the likelihood of overweight and obesity. It is, however, unclear from an energy balance

perspective as to why physical activity accrued in bouts provides a benefit on adiposity beyond that of total physical activity when the intensity is matched. Although speculative at this time, it is possible that physical activity accrued in bouts influences another component of energy balance such as energy intake, resting energy expenditure, or excess post-exercise oxygen consumption (EPOC). Duration, as well as intensity, of physical activity has been found to increase EPOC, and therefore increase total caloric expenditure, in adults.¹⁹ Further studies are needed to elucidate the biological mechanism by which bouts of physical activity impacts adiposity.

The recently published Evidence Based Physical Activity guidelines for school-aged children² along with other national and international physical activity recommendations for youngsters²⁰⁻²² advocate daily physical activity. Most of these guidelines recommend that children and youth accumulate 60 or more minutes of physical activity per day, with no stipulations as to how the physical activity should be accumulated. Conversely, in addition to providing information on the appropriate volume of physical activity, Canada's Physical Activity Guidelines for Children and Youth recommend that the physical activity be accumulated in bouts of at least 5-10 minutes in duration.^{23,24} We are unaware of any prior evidence to support the recommendation of accruing physical activity in bouts; however, the findings of the present study provide support for the Canadian recommendation, at least for obesity prevention. Our results also suggest that physical activity bouts lasting longer than 10 minutes in length benefits adiposity beyond the effects of shorter bouts.

The strengths of this study include the use of a large and representative study sample. The use of accelerometers provided us with accurate measures of total physical

activity and the ability to determine how each participants' activity was accumulated. The primary study limitation was the cross-sectional and observational nature, which prevents us from making causal inferences about the relation between physical activity and adiposity. Although objective in nature, accelerometers are not perfect measures of physical activity, and their main limitation is the inability to capture certain types of physical activity such as swimming and bicycling.²⁵ Our findings are also limited to a single health outcome. Although overweight is an important health measure in youth, and one that is predictive of several other immediate and long-term physical and psychosocial health measures,²⁶⁻²⁸ the findings of this study may not be consistent for other health outcomes. Finally, the bout lengths considered in this study were chosen arbitrarily based on 5 minute increments and the distribution of physical activity within the study population. It is unclear what the optimal bout length is for children and youth.

In conclusion, within this large and representative sample of school-aged youth, bouts of physical activity conferred benefits on adiposity status above those of the volume of physical activity. To more fully appreciate the effects of physical activity bouts on the health of children and youth, further studies are needed to determine the optimal bout length and to examine the influence of bouts of physical activity on other health outcomes.

References

1. Welk GJ, Corbin CB, Dale D. Measurement issues in the assessment of physical activity in children. *Res Q Exerc Sport* 2000;71(2 Suppl):S59-73.
2. Strong WB, Malina RM, Blimkie CJ, et al. Evidence based physical activity for school-age youth. *J Pediatr* 2005;146(6):732-7.
3. Physical Activity and Young People. 2008. (Accessed February 18, 2008, at http://www.who.int/dietphysicalactivity/factsheet_young_people/en/index.html.)
4. Centers for Disease Control and Prevention (CDC). National Health and Nutrition Examination Survey Data. In: Department of Health and Human Services, Centers for Disease Control and Prevention, Hyattsville, MD: U.S.; 2003-2004.
5. Trost SG, Pate RR, Freedson PS, Sallis JF, Taylor WC. Using objective physical activity measures with youth: how many days of monitoring are needed? *Med Sci Sports Exerc* 2000;32(2):426-31.
6. Van Coevering P, Harnack L, Schmitz K, Fulton JE, Galuska DA, Gao S. Feasibility of using accelerometers to measure physical activity in young adolescents. *Med Sci Sports Exerc* 2005;37(5):867-71.
7. Masse LC, Fuemmeler BF, Anderson CB, et al. Accelerometer data reduction: a comparison of four reduction algorithms on select outcome variables. *Med Sci Sports Exerc* 2005;37(11 Suppl):S544-54.
8. Treuth MS, Schmitz K, Catellier DJ, et al. Defining accelerometer thresholds for activity intensities in adolescent girls. *Med Sci Sports Exerc* 2004;36(7):1259-66.

9. Guinhouya CB, Hubert H, Soubrier S, Vilhelm C, Lemdani M, Durocher A. Moderate-to-vigorous physical activity among children: discrepancies in accelerometry-based cut-off points. *Obesity (Silver Spring)* 2006;14(5):774-7.
10. Andersen LB, Harro M, Sardinha LB, et al. Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study). *Lancet* 2006;368(9532):299-304.
11. Puyau MR, Adolph AL, Vohra FA, Butte NF. Validation and calibration of physical activity monitors in children. *Obes Res* 2002;10(3):150-7.
12. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *Bmj* 2000;320(7244):1240-3.
13. U.S. Department of Health and Human Services and National Center for Health Statistics. Documentation, Codebook, and Frequencies, Dietary Interview- Total Nutrient Intakes (First Day). In: Department of Health and Human Services, Centers for Disease Control and Prevention, Hyattsville, MD: U.S.; 2007.
14. Zhang J, Yu KF. What's the relative risk? A method of correcting the odds ratio in cohort studies of common outcomes. *Jama* 1998;280(19):1690-1.
15. Rizzo NS, Ruiz JR, Oja L, Veidebaum T, Sjostrom M. Associations between physical activity, body fat, and insulin resistance (homeostasis model assessment) in adolescents: the European Youth Heart Study. *Am J Clin Nutr* 2008;87(3):586-92.
16. Dencker M, Thorsson O, Karlsson MK, et al. Daily physical activity related to body fat in children aged 8-11 years. *J Pediatr* 2006;149(1):38-42.

17. Ness AR, Leary SD, Mattocks C, et al. Objectively measured physical activity and fat mass in a large cohort of children. *Plos Medicine* 2007;4(3):476-84.
18. Janssen I, Katzmarzyk PT, Boyce WF, et al. Comparison of overweight and obesity prevalence in school-aged youth from 34 countries and their relationships with physical activity and dietary patterns. *Obes Rev* 2005;6(2):123-32.
19. Borsheim E, Bahr R. Effect of exercise intensity, duration and mode on post-exercise oxygen consumption. *Sports Med* 2003;33(14):1037-60.
20. Kavey RE, Daniels SR, Lauer RM, Atkins DL, Hayman LL, Taubert K. American Heart Association guidelines for primary prevention of atherosclerotic cardiovascular disease beginning in childhood. *J Pediatr* 2003;142(4):368-72.
21. Corbin CB, Pangrazi RP. *Physical Activity for Children: a statement of guidelines for children aged 5-12*. 2nd ed. Reston, VA: National Academy for Sport and Physical Education; 2004.
22. Williams CL, Hayman LL, Daniels SR, et al. Cardiovascular health in childhood: A statement for health professionals from the Committee on Atherosclerosis, Hypertension, and Obesity in the Young (AHOY) of the Council on Cardiovascular Disease in the Young, American Heart Association. *Circulation* 2002;106(1):143-60.
23. Health Canada and Canadian Society for Exercise Physiology. *Canada's Physical Activity Guide to Healthy Active Living: Family Guide to Physical Activity for Youth 6-9 Years of Age*. In. Ottawa, ON: Minister of Health; 2002.
24. Health Canada and the Canadian Society for Exercise Physiology. *Canada's Physical Activity Guide to Healthy Active Living: Family Guide to Physical Activity for Youth 10-14 Years of Age*. In. Ottawa, ON: Minister of Health; 2002.

25. Goran MI. Measurement issues related to studies of childhood obesity: assessment of body composition, body fat distribution, physical activity, and food intake. *Pediatrics* 1998;101(3 Pt 2):505-18.
26. Krebs NF, Jacobson MS. Prevention of pediatric overweight and obesity. *Pediatrics* 2003;112(2):424-30.
27. Reilly JJ, Methven E, McDowell ZC, et al. Health consequences of obesity. *Arch Dis Child* 2003;88(9):748-52.
28. Whitaker RC, Wright JA, Pepe MS, Seidel KD, Dietz WH. Predicting obesity in young adulthood from childhood and parental obesity. *N Engl J Med* 1997;337(13):869-73.

TABLE 1 - Subject characteristics

	Total (n = 2498)	Males (n = 1263)	Females (n = 1235)
Age, y	12.7 ± 2.8	12.8 ± 2.7	12.6 ± 2.8
Race/Ethnicity, %			
Non-Hispanic white	24.8	24.5	25.0
Non-Hispanic black	33.2	35.1	31.3
Hispanic	37.6	36.3	38.9
Other	4.4	4.1	4.8
Overweight but not obese, %	21.2	21.5	20.8
Obese, %	15.0	13.6	16.4
Physical Activity Components			
Total, min/d	26.5 ± 21.9	34.3 ± 23.5	18.6 ± 16.8
Sporadic, % of total	66.0 ± 22.2	60.4 ± 21.2	71.7 ± 21.7
Short bouts, % of total	15.7 ± 11.3	16.9 ± 10.3	14.5 ± 12.1
Medium-to-long bouts, % of total	18.3 ± 19.5	22.7 ± 19.8	13.7 ± 18.1

Data presented as mean ± SD for continuous variables or prevalence (%) for categorical variables.

TABLE 2 - Correlation (r values) between the physical activity measures

	Sporadic	Short bouts	Medium-to-long bouts
Total	0.78	0.75	0.75
Sporadic	1.00	0.59	0.43
Short bouts		1.00	0.53
Medium-to-long bouts			1.00

All correlations are significant ($P < 0.0001$)

TABLE 3 - Bivariate relation between total physical activity and its components with overweight

Physical Activity Component	Physical Activity Category	Range (mean min/day)	Risk Ratio (95% CI) for Overweight
Total	Low	0.0 – 10.6	(referent)
	Low-moderate	10.6 – 21.0	0.75 (0.61-0.92)*
	Moderate-high	21.1 – 35.8	0.61 (0.47-0.78)*
	High	35.8 – 182.0	0.33 (0.24-0.47)*
			$p_{\text{trend}} < 0.05$
Sporadic	Low	0.0 – 7.3	(referent)
	Low-moderate	7.4 – 12.8	0.79 (0.63-0.97)*
	Moderate-high	12.9 – 20.2	0.66 (0.51-0.83)*
	High	20.2 – 103.0	0.50 (0.34-0.70)*
			$p_{\text{trend}} < 0.05$
Short bouts	Low	0.0 – 1.0	(referent)
	Low-moderate	1.1 – 3.3	0.87 (0.70-1.06)
	Moderate-high	3.4 – 6.7	0.68 (0.53-0.84)*
	High	6.7 – 45.0	0.39 (0.28-0.54)*
			$p_{\text{trend}} < 0.05$
Medium-to-long bouts	None	0.0	(referent)
	Low-moderate	1.4 – 4.3	0.72 (0.56-0.90)*
	Moderate-high	4.3 – 11.0	0.56 (0.41-0.74)*
	High	11.2 – 128.9	0.41 (0.30-0.55)*
			$p_{\text{trend}} < 0.05$

*Significantly different from referent group ($p < 0.05$)

CI; confidence interval.

All analyses were adjusted for sex, age, race/ethnicity, poverty-to-income ratio, smoking status, and total caloric intake.

TABLE 4 - Multivariate relation between physical activity components and overweight

Physical Activity Component	Physical Activity Category	Range of Physical Activity (min/d)	Risk Ratio (95% CI) for Overweight	
			Model 1	Model 2
Total	Low	0.0 – 10.6	(referent)	(referent)
	Low-moderate	10.6 – 21.0	0.89 (0.70-1.08)	0.88 (0.73-1.04)
	Moderate-high	21.1 – 35.8	0.86 (0.61-1.14)	0.89 (0.65-1.16)
	High	35.8 – 182.0	0.67 (0.39-1.04)	0.73 (0.44-1.10)
			$p_{\text{trend}} \text{ NS}$	$p_{\text{trend}} \text{ NS}$
Sum of bouts (short + medium -to-long)	Low	0.0 – 2.0	(referent)	N/A
	Low-moderate	2.1 – 6.9	0.82 (0.58-1.09)	
	Moderate-high	7.0 – 16.0	0.75 (0.52-1.01)	
	High	16.1 – 137.4	0.50 (0.27-0.84)*	
			$p_{\text{trend}} < 0.05$	
Short bouts	Low	0.0 – 1.0	N/A	(referent)
	Low-moderate	1.1 – 3.3		1.01 (0.85-1.18)
	Moderate-high	3.4 – 6.7		0.89 (0.70-1.09)
	High	6.7 – 45.0		0.67 (0.46-0.93)*
				$p_{\text{trend}} < 0.05$
Medium-to-long bouts	None	0.0	N/A	(referent)
	Low-moderate	1.4 – 4.3		0.80 (0.59-1.04)
	Moderate-high	4.3 – 11.0		0.72 (0.53-0.95)*
	High	11.2 – 128.9		0.66 (0.43-0.96)*
				$p_{\text{trend}} < 0.05$

*Significantly different from referent group ($p < 0.05$)

CI = confidence interval; N/A = not applicable (not included in multivariate analyses);

NS= not significant

All analyses were adjusted for sex, age, race/ethnicity, poverty-to-income ratio, smoking status, and total caloric intake

CHAPTER 6

Manuscript 4

*Relationship between Physical Activity and Screen Time Behaviours
in Canadian Youth*

Guideline component: This manuscript performs a detailed analysis of the relationship between physical activity and screen time. The purpose was to explore whether one behaviour (e.g. Evidence Based Physical Activity guidelines) or both behaviours (e.g. Canada's Physical Activity guidelines) should be targeted.

ABSTRACT

The purpose of this study was to perform a detailed analysis of the relationship between screen time and physical activity in youth. The sample included 5607 Canadian youth from the 2001/02 *Health Behaviour in School-aged Children Survey*. We considered physical activity form (structured vs. informal) and environment (at school vs. outside of school), and screen time behaviours (television, computer, total). Logistic regression analysis was used to determine if screen time predicted physical inactivity, and if physical activity predicted high screen time. In general, screen time level did not predict physical activity level with one exception. For organized sport outside of school, individuals in the highest screen time quartile were 25% more likely to be physically inactive compared to individuals in the lowest screen time quartile. These results provide little support for the contention that screen time is replacing physical activity, emphasizing the need for interventions that separately target these behaviours.

Keywords: television, computers, physical activity, youth

INTRODUCTION

Adolescents spend a startling amount of time watching television and using computer and videogame devices. The average Canadian youth in grades 6-10 accumulates more than 4 hours of total screen time (television + computer) per day, and less than 20% meet the screen time guidelines of two hours or less per day.¹

It is widely speculated that time spent in front of the television and computer screen is displacing time engaging in physical activity.² Studies examining the relationship between screen time and physical activity show conflicting results and do not all support the displacement theory. The number of studies reporting significant relationships³⁻⁶ is comparable to the number reporting no associations.⁷⁻¹¹ Although there is no clear indication of what factor(s) accounts for the discrepancy, it may in part be explained by inconsistencies in the measures of physical activity. Since health outcomes such as obesity are positively related to screen time^{7, 12} and inversely related to physical activity,^{13, 14} deciphering the relation between these behaviours is critical for the development of appropriate public health interventions (i.e. should interventions target one or both behaviours).

A limitation of previous studies examining this relation is the use of a composite measure of physical activity. Within young people organized and unorganized forms of physical activity are poorly related, as is the amount of physical activity performed in the school and home environments.^{15, 16} Because screen time is largely accumulated in an unstructured way at home, we hypothesized that screen time will only be related to physical activity participation outside of school, primarily unstructured forms. Figure 1

illustrates the hypothesized role of the physical activity environment within the theoretical framework of the study.

Intervention studies provide valuable insight into the relation between screen time and physical activity. Three interventions designed to reduce television all reduced screen time,¹⁷⁻¹⁹ but only one observed significant improvements in physical activity.¹⁹ The inclusion of parents in the education sessions was a distinguishing feature of this intervention. This suggests the potential importance of parents in the adoption of active behaviours. This lead to the next component of our theoretical framework (Figure 1) where we hypothesized that the relation between screen time and physical activity would be stronger in youth living in supportive family environments in that parents in supportive homes would be more likely to ensure their children replaced screen time with physical activity.

Therefore, the purpose of this study was to perform a detailed analysis of the relationship between physical activity and screen time behaviours in youth. More specifically, we considered different forms of physical activity (structured vs. informal), different physical activity environments (at school vs. outside of school), various screen time behaviours (television vs. computer vs. total), as well as the potential influence of the level of family support. We anticipated that the findings would provide a greater understanding of the relationship between physical activity and sedentary behaviours, which could assist in the development of evidence-informed interventions aimed at increasing physical activity in youth.

METHODS

Design

Results are based on the Canadian records from the 2001/02 World Health Organization *Health Behaviour in School-Aged Children Survey* (HBSC). The HBSC is a cross-sectional survey from 35 countries.²⁰ The survey consisted of a classroom based questionnaire administered during school time. The Canadian data were collected from January to May of 2002. The sample was designed using a cluster design with the school class being the basic cluster, the distribution of the students reflecting the distribution of Canadians in grades 6-10 (reflecting ages 10-16 years); the sample was self-weighting.²⁰ Samples were selected to represent distributions of schools by size, location, language, and religion. The questionnaire was completed by 74.2% of the eligible students and their demographic profile was representative of Canadians in the same age range. A more detailed description of the HBSC methodology is provided in Appendix C.

Sample

The sample included 7266 students; analysis was limited to those students who completed the survey questions related to television, computer use, physical activity, material wealth, and family climate resulting in a final sample size of 5607. Of the 1659 students excluded, there were a higher proportion of grade six students (41.5% vs. 24.7%) and more males (51.8% vs. 44.8%) than in the sample included in the analysis.

The Canadian *HBSC* was approved by the Queen's University General Research Ethics Board. Consent was obtained from the participating school boards, individual schools, parents, and students. Student participation was voluntary.

Measures

The amount of time spent watching television and using the computer were determined using the questions: “About how many hours a day do you usually watch television (including videos) in your free time?” and “About how many hours a day do you usually use a computer (for playing games, emailing, chatting or surfing on the internet) in your free time?”. Response options included: “none at all”, “about half an hour a day”, “about 1 hour a day”, “about 2 hours a day”, “about 3 hours a day”, “about 4 hours a day”, “about 5 hours a day”, “about 6 hours a day”, or “about 7 or more hours a day”. Students reported on both weekday and weekend use, and a weighted mean was calculated to determine the average daily time spent watching television and using the computer. Total screen time represents the sum of television and computer hours.

The amount of physical activity during school as part of physical education class was assessed by asking “About how many hours a week do you usually take part in physical activity that makes you out of breath or warmer than usual in your class time at school?”. Free time physical activity at school was assessed by the question “About how many hours a week do you usually take part in physical activity that makes you out of breath or warmer than usual in your free time at school?”. Time spent in organized sport outside of school was assessed by asking “About how many hours a week do you usually take part in physical activity that makes you out of breath or warmer than usual outside of school while participating in lessons or league or team sports?”. Finally, time spent participating in informal physical activity outside of school was determined by asking “About how many hours a week do you usually take part in physical activity that makes you out of breath or warmer than usual outside of school while participating in informal activities, either on your own or with friends?”. Response options for all questions were

“none at all”, “about ½ hour”, “about 1 hour”, “about 2 hours”, “about 3 hours”, “about 4 hours”, “about 5 hours”, “about 6 hours”, “about 7 or more hours”.

The three-point Family Affluence Scale (low, medium or high) was used as a measure of socioeconomic status and is based on four measures of material wealth including car ownership, bedroom sharing, holiday travel, and computer ownership.²⁰

Family climate was based on questions regarding students’ opinion on ease of communication with parents, parental trust, parental understanding and happiness of home life. Response options were based on a five-point Likert scale ranging from strongly agree (score of 1) through strongly disagree (score of 5). Family climate score was calculated as the mean of the responses to the six questions. Mean scores of <2.5, 2.5-3.5, and >3.5 represent high, moderate, and low family climate, respectively. The low and moderate family climate groups were combined for the stratified analyses.

Statistical Analysis

Spearman rank correlations were used to examine the relationship between television, computer, and total screen time with the four physical activity measures. A sample of Spearman correlation output is presented in Appendix G. The screen time and physical activity measures were ranked into quartiles. Logistic regression analysis was used to determine if the likelihood of being physically inactive (lowest quartile) varied according to screen time quartiles, and if the likelihood of being a high screen time watcher varied according to physical activity quartiles. Grade, sex, material wealth, and family climate were included as covariates in all regression models. To examine the possible moderating effect of age, sex and family climate, additional analyses were performed which included interaction terms (screen time X sex, screen time X age, or

screen time X family climate; or PA X age, sex, or family climate). All regression analyses were performed on the total sample and then stratified across level of family climate (low-moderate vs. high), age (grade 6-8 vs. 9-10), and sex. A sample of a logistic regression output is presented in Appendix J. Statistical analyses were performed using SAS version 9.1 (SAS Institute, Cary, North Carolina, USA).

RESULTS

Descriptive information on the screen time and physical activity measures is presented in Table 1. On average, adolescent males and females spent approximately 35 and 30 hours/week, respectively, engaging in screen time activities. Participation in the various forms of physical activity ranged from 3.0-3.4 hours/week in males and from 2.3-2.8 hours/week in females.

Time spent watching television, playing on the computer, and total screen time were not significantly correlated with any of the physical activity measures with the exception of a slight negative correlation ($r = -0.044$) between time spent watching television and participating in organized sport outside of school (Table 2). When stratified across levels of family climate, the significant correlation was only maintained for the high family climate group (Table 2). Similar observations were made when age (grades 6-8 and 9-10) and gender subgroup analyses were performed (data not shown).

Logistic regression analyses results in which screen time quartiles were used to predict physically inactive youth (lowest quartile) are shown in Table 3. None of the odds ratios reached statistical significance ($P > 0.05$) with one exception. For organized sport outside of school, individuals in the highest screen time quartile were 25% more

likely to be physically inactive compared to individuals in the lowest screen time quartile ($P=0.01$). Similar results were found when the analyses were stratified by family climate level (Table 3).

Table 4 shows the results of the logistic regression analyses in which physical activity quartiles were used to predict youth within the highest screen time quartile. None of the odds ratios reached statistical significance ($P>0.05$) with one exception. For organized sport outside of school, individuals in the lowest physical activity quartile were 39% more likely to be high screen time viewers than individuals in the highest physical activity quartile ($P=0.01$). When stratified by level of family climate, the results were comparable to those found in the total sample (Table 4).

To explore the potential moderating effects of age (grade 6-8 vs. grade 9-10), sex, and family climate (low/moderate vs. high) on the results presented in Tables 3 and 4, the logistic regression analyses were repeated with the inclusion of interaction terms. Only three of the interaction terms were significant. We performed subgroup analyses for the models in which significant interaction terms were found to highlight the moderating effect of age, gender, or family climate. First, for physical activity performed in free time at school, the likelihood of being within the highest screen time quartile was significantly increased in the lowest physical activity quartile in males (odds ratio = 1.30, 95% confidence intervals = 1.05-1.62) but not females (0.89, 0.72-1.10). Second, the likelihood of being in the lowest physical activity quartile for free time physical activity at school was significantly increased in high screen time users in grade 9-10 students (1.48, 1.13-1.93) but not in grade 6-8 students (0.91, 0.74-1.11). Third, grade 9-10 students in the upper screen time quartile were more likely to be in the lowest physical

activity quartile for informal physical activity outside of school (1.48, 1.11-1.96) while no relation was observed among grades 6-8 students (0.94, 0.76-1.16). Family climate did not moderate any of the relations between physical activity and screen time (Tables 3 and 4).

DISCUSSION

The primary finding in this large study of 6th-10th grade Canadian youth was that, by and large, the time youth spent participating in physical activity was not related to the time they spent sitting in front of the television and computer screen. Although we did observe a few significant relationships, in general they were sparse (<15% of the relations examined) and of a small effect size. In contrast to our theoretical framework (Figure 1), the relationship between screen time and physical activity was not moderated by family climate or the physical activity environment.

Our results are consistent with a number of other studies.⁷⁻¹⁰ The distinguishing feature of the present study is consideration of different forms (structured vs. informal) and environments (school vs. outside of school) of physical activity. By comparison, previous studies employed a global measure of physical activity. Our study was also unique in that we examined the influence of family climate on the relationship between physical activity and screen time.

Although our study and many previous studies have shown little or no relation between physical activity and screen time in adolescents, two studies have reported the opposite.^{3,6} The first study found that, by comparison to those participating in moderate-to-vigorous physical activity on 6-7 days/week, those engaging in activity on 3-5

days/week or ≤ 2 days/wk were 50-100% more likely to watch >4 hours/day of television.³ The second study was a longitudinal study of 7th and 8th graders.⁶ The study found that participation in physical activity outside of school was strongly and independently related to baseline and changes in television but not video game playing. The reason for the inconsistent findings is unclear. We hypothesized that consideration of different forms of physical activity and physical activity environments would shed some light on the relation, but this was not the case.

Despite parent involvement being a distinguishing feature of the intervention successful at reducing screen time while increasing physical activity,¹⁹ family climate had a minimal impact on our results and may reflect differences in study design. The intervention involved parents in the behaviour modification where as our cross-sectional study assessed parental influence based on students' perception of their parental support and the strength of the relationship with their parents. In addition, the participants in our study were older (10-16 years) compared to those in the intervention (8-12 years), which could also affect parental influence.

Independent of any possible effect on physical activity, reducing screen time in youth is important considering that it is related to obesity,^{7, 12} snacking on calorically dense foods,²¹ exposure to violence, sexual content, negative body image, and irresponsible alcohol use.²² Negative health implications of high screen time could be negated by the benefits of physical activity. In youth, physical activity has a positive influence on blood lipids, blood pressure, body composition, glucose metabolism, and psychological health (see review²³). Youth who engage in physical activity with parents are less likely to engage in high risk behaviours such as smoking, alcohol and drug use.²⁴

The opposite effects of screen time and physical activity on health outcomes provides further support for our recommendation that interventions should target both behaviours.

The primary limitation of this study was that the measures of screen time and physical activity were based on self-reports. Concerning the validity of self-reported measures of screen time, a previous study reported that questionnaire assessed television time modestly correlated ($r=0.47$) to television time measured by a detailed log, underestimating time by about 0.09 hours per week.²⁵ Questionnaire measures of physical activity are reported to be reliable and modestly correlated ($r=0.40$) with direct measures,²⁶ but tend to over predict actual physical activity levels.²⁷ The use of self-report measures likely resulted in an underestimation of socially undesirable activities (screen time) and over-reporting of social desirable behaviours (physical activity).²⁷ This lack of precision would have resulted in non-differential misclassification and may explain the lack of strong and significant associations observed in the present study. The broad response options for the questions may have further limited our ability to detect subtle differences. The cross-sectional design of the study does not allow for a cause and effect relationships to be concluded. Measures of race/ethnicity, parental education, residential location, and number of siblings were not available and could not be included as covariates in the analyses. Given the lack of associations, it is unlikely that inclusion of these potential covariates would have impacted our findings. Finally, the study sample was slightly older and contained more females than the total HBSC sample, limiting the generalizability of the results.

The results from this study provide little support to the contention that time spent in front of the television and computer is replacing time spent engaging in physical

activity, regardless of the type of screen time and physical activity and the environments in which these behaviours are performed. Despite some methodological weaknesses, in the absence of stronger evidence to the contrary, these findings indicate that interventions should consider targeting both screen time and physical activity. Targeting both of these behaviours may help ensure that time previously spent engaging in screen time behaviours would be replaced by physical activity and not by other sedentary behaviours. Intervention studies are needed to test the hypothesis generated from this cross-sectional study.

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References

1. Mark A, Boyce W, Janssen I. Television viewing, computer use, and total screen time in Canadian youth. *Paediatr Child Health* 2006;11(9):595-9.
2. Bryant MJ, Lucove JC, Evenson KR, Marshall S. Measurement of television viewing in children and adolescents: a systematic review. *Obes Rev* 2007;8(3):197-209.
3. Eisenmann JC, Bartee RT, Wang MQ. Physical activity, TV viewing, and weight in U.S. youth: 1999 Youth Risk Behavior Survey. *Obes Res* 2002;10(5):379-85.
4. DuRant RH, Baranowski T, Johnson M, Thompson WO. The relationship among television watching, physical activity, and body composition of young children. *Pediatrics* 1994;94(4 Pt 1):449-55.
5. Marshall SJ, Biddle SJ, Gorely T, Cameron N, Murdey I. Relationships between media use, body fatness and physical activity in children and youth: a meta-analysis. *Int J Obes Relat Metab Disord* 2004;28(10):1238-46.
6. Motl RW, McAuley E, Birnbaum AS, Lytle LA. Naturally occurring changes in time spent watching television are inversely related to frequency of physical activity during early adolescence. *J Adolesc* 2006;29(1):19-32.
7. Andersen RE, Crespo CJ, Bartlett SJ, Cheskin LJ, Pratt M. Relationship of physical activity and television watching with body weight and level of fatness among children: results from the Third National Health and Nutrition Examination Survey. *JAMA* 1998;279(12):938-42.
8. Robinson TN, Hammer LD, Killen JD, et al. Does television viewing increase obesity and reduce physical activity? Cross-sectional and longitudinal analyses among adolescent girls. *Pediatrics* 1993;91(2):273-80.

9. Gordon-Larsen P, McMurray RG, Popkin BM. Determinants of adolescent physical activity and inactivity patterns. *Pediatrics* 2000;105(6):E83.
10. Berkey CS, Rockett HR, Gillman MW, Colditz GA. One-year changes in activity and in inactivity among 10- to 15-year-old boys and girls: relationship to change in body mass index. *Pediatrics* 2003;111(4 Pt 1):836-43.
11. Taveras EM, Field AE, Berkey CS, et al. Longitudinal relationship between television viewing and leisure-time physical activity during adolescence. *Pediatrics* 2007;119(2):e314-9.
12. Crespo CJ, Smit E, Troiano RP, Bartlett SJ, Macera CA, Andersen RE. Television watching, energy intake, and obesity in US children: results from the third National Health and Nutrition Examination Survey, 1988-1994. *Arch Pediatr Adolesc Med* 2001;155(3):360-5.
13. Andersen LB, Harro M, Sardinha LB, et al. Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study). *Lancet* 2006;368(9532):299-304.
14. Gutin B, Yin Z, Humphries MC, Barbeau P. Relations of moderate and vigorous physical activity to fitness and fatness in adolescents. *Am J Clin Nutr* 2005;81(4):746-50.
15. Mota J, Santos P, Guerra S, Ribeiro JC, Duarte JA. Patterns of daily physical activity during school days in children and adolescents. *Am J Hum Biol* 2003;15(4):547-53.
16. Trost SG, Pate RR, Freedson PS, Sallis JF, Taylor WC. Using objective physical activity measures with youth: how many days of monitoring are needed? *Med Sci Sports Exerc* 2000;32(2):426-31.

17. Robinson TN. Reducing children's television viewing to prevent obesity: a randomized controlled trial. *JAMA* 1999;282(16):1561-7.
18. Gortmaker SL, Peterson K, Wiecha J, et al. Reducing obesity via a school-based interdisciplinary intervention among youth: Planet Health. *Arch Pediatr Adolesc Med* 1999;153(4):409-18.
19. Epstein LH, Paluch RA, Gordy CC, Dorn J. Decreasing sedentary behaviors in treating pediatric obesity. *Arch Pediatr Adolesc Med* 2000;154(3):220-6.
20. Currie C, Samdal O, Boyce W, Smith B. Health Behaviour in School-Aged Children: a World Health Organization Cross-National Study. Research Protocol for the 2001/02 Survey. Edinburgh, Scotland: Child and Adolescent Health Research Unit, University of Edinburgh; 2001 (http://www.hbsc.org/overview_studydesign.html).
21. Robinson TN. Television viewing and childhood obesity. *Pediatr Clin North Am* 2001;48(4):1017-25.
22. Brown JD, Witherspoon EM. The mass media and American adolescents' health. *J Adolesc Health* 2002;31(6 Suppl):153-70.
23. Blair SN, Cheng Y, Holder JS. Is physical activity or physical fitness more important in defining health benefits? *Med Sci Sports Exerc* 2001;33(6 Suppl):S379-99; discussion S419-20.
24. Nelson MC, Gordon-Larsen P. Physical activity and sedentary behavior patterns are associated with selected adolescent health risk behaviors. *Pediatrics* 2006;117(4):1281-90.

25. Schmitz KH, Harnack L, Fulton JE, et al. Reliability and validity of a brief questionnaire to assess television viewing and computer use by middle school children. *J Sch Health* 2004;74(9):370-7.
26. Prochaska JJ, Sallis JF, Long B. A Physical Activity Screening Measure for Use With Adolescents in Primary Care. *Arch Pediatr Adolesc Med* 2001;155(5):554-9.
27. Sirard JR, Pate RR. Physical activity assessment in children and adolescents. *Sports Med* 2001;31(6):439-54.

Table 1. Descriptive information for screen time and physical activity variables.

	Males (n=2514)		Females (n=3093)	
	Grade 6-8	Grade 9-10	Grade 6-8	Grade 9-10
Screen Time Measure				
Television (hr/wk)	21.2 (11.5)	20.0 (11.0)	19.0 (11.0)	17.5 (10.4)
Computer (hr/wk)	12.8 (11.8)	15.1 (12.9)	10.4 (9.9)	11.8 (10.3)
Total (hr/wk)	34.0 (18.4)	35.1 (18.9)	29.4 (16.6)	29.3 (15.8)
Physical Activity at School				
Class Time (hr/wk)	3.1 (2.3)	3.1 (2.4)	2.7 (2.1)	2.7 (2.3)
Free Time (hr/wk)	3.0 (2.4)	3.1 (2.5)	2.6 (2.2)	2.3 (2.2)
Physical Activity outside of School				
Organized Sport (hr/wk)	3.0 (2.5)	3.0 (2.7)	2.7 (2.4)	2.5 (2.6)
Informal Activity (hr/wk)	3.3 (2.4)	3.4 (2.5)	2.8 (2.2)	2.8 (2.3)

Data presented as means (SD).

Table 2. Correlations (r values) between physical activity and screen time variables.

	Television	Computer	Total Screen Time
Total (n=5607)			
Physical Activity at School			
Class Time	0.009	-0.017	-0.008
Free Time	-0.006	-0.022	-0.019
Physical Activity outside of School			
Organized Sport	-0.044*	0.001	-0.037
Informal Activity	-0.026	-0.009	-0.030
Low-Moderate Family Climate (n=1520)			
Physical Activity at School			
Class Time	0.023	-0.014	0.005
Free Time	-0.012	-0.035	-0.033
Physical Activity outside of School			
Organized Sport	-0.041	-0.034	-0.018
Informal Activity	-0.026	-0.018	-0.036
High Family Climate (n=4087)			
Physical Activity at School			
Class Time	0.012	0.001	0.003
Free Time	0.011	0.005	0.008
Physical Activity outside of School			
Organized Sport	-0.045*	0.015	-0.032
Informal Activity	-0.013	0.016	-0.006

* P<0.05

Table 3. Odds ratios for physical inactivity (lowest physical activity quartile) according to screen time quartile.

Physical Activity Measure	Screen Time Quartile			
	1	2	3	4
Total[†] (n= 5607)				
Physical Activity at School				
Class Time	1.00	1.01 (0.86-1.19)	1.10 (0.93-1.29)	1.10 (0.94-1.30)
Free Time	1.00	0.91 (0.77-1.06)	0.98 (0.84-1.15)	1.09 (0.93-1.28)
Physical Activity Outside of School				
Organized Sport	1.00	0.84 (0.70-1.01)	0.98 (0.82-1.17)	1.25 (1.04-1.49)*
Informal Activity	1.00	1.04 (0.88-1.23)	1.10 (0.93-1.29)	1.10 (0.93-1.30)
Low-Moderate Family Climate[§] (n=1520)				
Physical Activity at School				
Class Time	1.00	0.98 (0.71-1.36)	1.03 (0.76-1.42)	1.10 (0.81-1.50)
Free Time	1.00	0.93 (0.68-1.29)	1.05 (0.77-1.43)	1.28 (0.94-1.73)
Physical Activity Outside of School				
Organized Sport	1.00	0.80 (0.58-1.12)	0.82 (0.59-1.12)	1.20 (0.88-1.63)
Informal Activity	1.00	1.02 (0.74-1.41)	1.00 (0.73-1.37)	1.14 (0.84-1.56)
High Family Climate[§] (n=4087)				
Physical Activity at School				
Class Time	1.00	1.03 (0.85-1.24)	1.13 (0.94-1.37)	1.11 (0.92-1.35)
Free Time	1.00	0.90 (0.75-1.09)	0.97 (0.80-1.17)	1.03 (0.85-1.24)
Physical Activity Outside of School				
Organized Sport	1.00	0.86 (0.68-1.07)	1.07 (0.86-1.33)	1.27 (1.01-1.58)*
Informal Activity	1.00	1.06 (0.87-1.28)	1.15 (0.95-1.39)	1.08 (0.89-1.32)

Data presented as odds ratios (95% confidence intervals). Lowest screen time quartile was used as the referent group. [†]Adjusted for age, sex, material wealth, family climate.

[§]Adjusted for age, sex, material wealth. *P=0.01

Table 4. Odds ratios for high screen time viewers (highest quartile) according to physical activity quartiles.

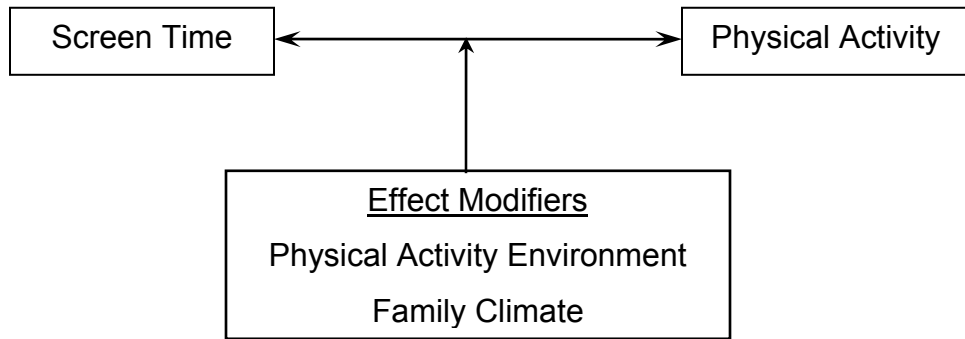
Physical Activity Measure	Physical Activity Quartile			
	4	3	2	1
Total[†] (n=5607)				
Physical Activity at School				
Class Time	1.00	0.94 (0.78-1.14)	0.91 (0.76-1.08)	1.02 (0.88-1.19)
Free Time	1.00	0.87 (0.71-1.07)	0.95 (0.80-1.12)	1.08 (0.93-1.26)
Physical Activity Outside of School				
Organized Sport	1.00	1.11 (0.93-1.33)	1.04 (0.87-1.25)	1.39 (1.16-1.68)*
Informal Activity	1.00	1.06 (0.89-1.27)	1.02 (0.84-1.25)	1.09 (0.91-1.30)
Low-Moderate Family Climate[§] (n=1520)				
Physical Activity at School				
Class Time	1.00	1.07 (0.75-1.50)	0.92 (0.66-1.27)	1.08 (0.82-1.43)
Free Time	1.00	0.85 (0.57-1.27)	1.10 (0.81-1.50)	1.30 (0.97-1.73)
Physical Activity Outside of School				
Organized Sport	1.00	1.26 (0.87-1.81)	1.06 (0.74-1.53)	1.54 (1.09-2.19)*
Informal Activity	1.00	1.16 (0.82-1.63)	1.03 (0.71-1.49)	1.22 (0.87-1.73)
High Family Climate[§] (n=4087)				
Physical Activity at School				
Class Time	1.00	0.90 (0.72-1.11)	0.90 (0.74-1.11)	1.00 (0.84-1.20)
Free Time	1.00	0.88 (0.69-1.11)	0.90 (0.74-1.10)	1.01 (0.84-1.21)
Physical Activity Outside of School				
Organized Sport	1.00	1.07 (0.87-1.32)	1.04 (0.84-1.28)	1.35 (1.08-1.69)*
Informal Activity	1.00	1.03 (0.84-1.26)	1.04 (0.82-1.33)	1.04 (0.84-1.29)

Data presented as odds ratios (95% confidence intervals). Highest physical activity quartile was used as the referent group. [†]Adjusted for age, sex, material wealth, family climate. [§]Adjusted for age, sex, material wealth. *P=0.01

FIGURE CAPTION

Figure 1. Theoretical framework of the relationship between screen time and physical activity in adolescents. According to this framework screen time will be related to physical activity, but this relationship will only exist for physical activity occurring outside of school and for youth living in a supportive family environment.

Figure 1



CHAPTER 7

Manuscript 5

Television Viewing, Computer Use, and Total Screen Time in Canadian Youth

This manuscript is published in *Paediatrics and Child Health* 2006;11(9):595-599 and has been presented in a format consistent with the journal requirements.

Guideline component: This manuscript is a short descriptive study to determine the proportion of Canadian youth meeting screen time guidelines, and providing some indication as to whether the recommended screen time levels are attainable.

ABSTRACT

Background: Research has linked excessive television viewing and computer use in children and adolescents to a variety of health and social problems. Current recommendations are that screen time in children and adolescents should be limited to no more than two hours per day.

Objective: The purpose of the current study was to determine the percentage of Canadian youth meeting the screen time guidelines.

Methods: This representative study sample consisted of 6942 Canadian youth in grades 6-10 who participated in the 2001/02 World Health Organization *Health Behaviour in School-Aged Children Survey* (HBSC).

Results: Only 41% of Canadian females and 34% of males in grades 6 to 10 watched two or less hours of television per day. Once leisure time computer use was included and total daily screen time was examined, only 18% of females and 14% of males met the guidelines. The prevalence of females meeting the screen time guidelines was higher than in males.

Conclusion: Fewer than 20% of Canadian youth in grades 6-10 met the total screen time guidelines, suggesting that increased public health interventions are needed to reduce the number of leisure time hours that Canadian youth spend watching television and using the computer.

Keywords: screen time, television viewing, computer use, Canadian youth

INTRODUCTION

In the mid 1980's researchers identified television viewing as a correlate of childhood obesity,¹ a finding that has been confirmed by numerous other investigators.²⁻⁵ There is also substantive evidence that television viewing in children and adolescents is linked to numerous other health and social problems including violence and aggressive behaviour, physical inactivity, initiation of early sexual behaviours, body self-image issues, and substance use and abuse.⁶ Excessive use of computers, including video games, appears to be associated with many of the same problems as watching television.⁶

In 2001 the American Academy of Pediatrics released guidelines recommending that screen time (television + computer) in children and adolescents be limited to no more than two hours per day.⁷ This was followed in 2002 by a statement from the Canadian Paediatric Society indicating that most young people need to reduce their sedentary activities by 30 minutes per day,⁸ and a further statement by the Canadian Paediatrics Society in 2003 recommended limiting television to no more than two hours per day in school aged youth.⁹ As evidence of the high volume of television watching in young people, findings from a representative sample of 8-16 year old Americans indicate that 48% of males and 38% of females watch 2 or more hours of television per day.³ These figures do not include computer and video games use, and a study of children in California found that total screen time averaged 6.5 hours per day.¹⁰

At present there is an absence of information on total screen time in Canadian youth, and subsequently it is unknown as to what proportion of the population conforms to the guideline of 2 hours or less of screen time per day. Therefore, the purpose of this

study was to describe television, computer, and total screen time in a representative sample of Canadian youth.

METHODS

Study Population

These results are based on the Canadian records from the 2001/02 World Health Organization *Health Behaviour in School-Aged Children Survey* (HBSC). The authors of this study are part of the Canadian HBSC investigative team, and WB is the Principle Investigator. The HBSC is a cross-sectional survey from 35 countries.¹¹ The survey consisted of a classroom based questionnaire. The Canadian data were collected in the first half of 2002. The sample was designed according to the international HBSC protocol in that a cluster design was used with the school class being the basic cluster, the distribution of the students reflecting the distribution of Canadians in grades 6-10 (reflecting ages 10-16), and the sample was self-weighting.¹¹ Samples were selected to represent distributions of schools by size, location, language, and religion. 74.2% of the students selected for the study completed the questionnaire, and their demographic profile was representative of Canadians in the same age range. The sample included 7266 students; analysis was limited to those students who completed the survey questions related to television and computer use resulting in a sample size of 6942. A more detailed description of the HBSC methodology is provided in Appendix C.

The Canadian HBSC was approved by the Queen's University General Research Ethics Board. Consent was obtained from the participating school boards, individual schools, parents, and students. Student participation was voluntary.

Measurement of Screen Time

The amount of time spent watching television and using the computer were determined using the following questions: “About how many hours a day do you usually watch television (including videos) in your free time?” and “About how many hours a day do you usually use a computer (for playing games, emailing, chatting or surfing on the internet) in your free time?”. For each questions the response options were “none at all”, “about half an hour a day”, “about 1 hour a day”, “about 2 hours a day”, “about 3 hours a day”, “about 4 hours a day”, “about 5 hours a day”, “about 6 hours a day”, or “about 7 or more hours a day”. Questions were asked for both weekday and weekend use, and a weighted mean was calculated to determine the average amount of free time per day spent watching television and using the computer. Total screen time was calculated as the sum of television and computer hours. For television, computer, and total screen time subjects were categorized into those who did and did not meet the American Academy of Pediatrics⁷ and Canadian Paediatrics Society⁹ guidelines of 2 hours or less per day.

Statistical Analysis

Results were grouped by gender and age group (grades 6-8 and grades 9-10). Descriptive statistics were used to describe the distribution of the three screen time variables and to estimate the prevalence of those who engaged in 2 hours or less of screen time per day. χ^2 tests were used to compare prevalences across gender and age groups. A sample of a χ^2 output is presented in Appendix H. Statistical analyses were performed using SAS (SAS Institute, Cary, North Carolina, USA).

RESULTS

The study sample included 2410 females in grades 6-8, 1319 females in grades 9-10, 2213 males in grades 6-8, and 1000 males in grades 9-10. Percentile distributions for the various screen time measures are listed in Table 1. The 50th percentile for the various gender and age groups ranged from 2.29–2.71 hours per day for television viewing, 1.00–1.57 hours per day for computer use, and 3.71–4.71 hours per day for total screen time. Figure 1 illustrates the percentage of Canadian youth who engaged in 2 hours per day or less (i.e., those meeting the guidelines) of television viewing, computer use, and total screen time. The prevalence of those meeting the guidelines varied by gender and grade, with prevalences being higher in females than males and higher in grade 6-8 students than grade 9-10 students. Regardless of age group, the prevalence of females (41%) who watched 2 or less hours of television per day was higher than in males (34%). For leisure time computer use (not including homework), 72% of females and 65% of males used the computer for 2 or less hours per day. For total screen time (television + computer) only 18% of females and 14% of males met the guidelines of 2 hours or less per day.

DISCUSSION

Only 41% of Canadian females and 34% of males in grades 6 to 10 watched two or less hours of television per day. Once leisure time computer use was included and total daily screen time was examined, only 18% of females and 14% of males met the recommendations of 2 hours or less of entertainment media time per day. Fewer males and fewer older youth conformed to the screen time guidelines.

Data from a nationally representative sample of 14-18 year old Americans conducted in 1999 indicate that 37% of females and 34% of males watch less than two hours of television per day.¹² These values are quite comparable to those reported in this study for Canadian youth. In a different representative survey of 8-18 year old Americans conducted in 1998-1999, it was reported that boys and girls averaged 5.8 and 4.6 hours of screen time daily, respectively.¹⁰ Results from the current study indicate that the average screen time, while comparable, is slightly lower in 10-16 year old Canadian males (average 4.8 hours/day) and females (average 4.1 hours/day).

Cross-sectional studies indicate that children and adolescents who watch more than 2 or 3 hours of television per day are more likely to be overweight and obese compared to their peers who watch less than these amounts.^{5, 13} Understandably, youth who watch more television are less physically active.^{1, 12, 14-16} Furthermore, time spent watching television is positively correlated with snacking, especially on calorically dense foods.^{17, 18} The negative consequences of television and computer use are by no means limited to obesity. Spending more time watching television and playing video games increases one's exposure to violence, sexual content, negative body images, and irresponsible tobacco and alcohol use.⁶ For instance, during the first hour of prime time television three out of every four programs contain sexual messages (as many as 8 sexual incidences per hour) with little discussion relating to the risks and consequences of these behaviours.⁶ As for leisure time computer use, the most common video games are combat related, and it is widely speculated that playing these types of games may influence real-life violence.¹⁰ Thus, it is quite concerning that less than 20% of Canadian youth in grades 6-10 meet current entertainment media time guidelines. With that in

mind, to our knowledge no studies that have examined whether total screen time is related to risk behaviours and poor health outcomes, and in particular, whether total screen time is a better predictor of these outcomes than television or computer time alone. Further, as most of the current evidence is based on results from cross-sectional studies, longitudinal studies are needed to confirm the evidence.

Three randomized trials have addressed the issue of reducing television viewing in youth. The first was a school-based intervention in 3rd-4th graders that consisted of 18 lessons aimed at reducing television and video game use, followed by a challenge to limit use to 7 hours per week.¹⁹ Following the intervention, total screen time in the students attending the intervention schools was almost half that of the students attending the control schools (8.8 versus 14.5 hours/week).¹⁹ The second study was a school-based program for grade 6-7 students and consisted of lessons focused on reducing television viewing and consumption of high fat foods, and increasing physical activity and fruit and vegetable consumption.²⁰ After one year, students in the intervention schools were watching 0.6 hours per day less television than students in the control schools.²⁰ The third study randomized 90 obese children into one of four treatment groups, with each treatment consisting of educational therapy meetings with the children and their parents.²¹ The meetings were provided in either a low *or* high dose, and focused on either reducing sedentary behaviors *or* increasing physical activity. Following 6 months of treatment, targeted sedentary behaviours were significantly reduced in the group receiving the high dose of sedentary behavior reduction therapy. However the effects of the intervention were not as strong at the 24 month follow-up.²¹

Despite the demonstrated decreases in screen time, only one of the aforementioned intervention studies observed an increase in physical activity participation.²¹ Thus, although the overall goal of interventions should be to reduce total screen time to less than 2 hours per day,⁷ emphasis must also be placed on increasing physical activity so that time previously spent watching television and playing video games is not simply replaced by other sedentary behaviours such as reading or talking on the telephone with friends. The intervention should also incorporate guidelines for proper nutrition to help reduce snacking on calorically dense foods associated with television viewing.^{1, 17}

Limitations of the study include that television and computer use times were based on self-reports. It is also important to note that the survey did not ask specifically about videogames that may be played on the television (e.g., Nintendo, Play Station). Although some students would have included this under the computer games question, others may have not, suggesting that total screen time may have been underestimated in the present study. Strengths of the study include that it was based on a large data set representative of the Canadian school population. The derived measure of total screen time, including television and computer time, is also a strength as the vast majority of previous studies have been limited to television use.

Fewer than 20% of Canadian school youth in grades 6-10 meet the total screen time guidelines. Public health interventions need to be introduced to reduce the number of leisure time hours that Canadian youth spend watching television and using the computer. Interventions should provide students with education concerning the benefits of regular physical activity, proper nutrition, and appropriate social behaviours.

ACKNOWLEDGEMENTS

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References

1. Dietz WH, Jr., Gortmaker SL. Do we fatten our children at the television set? Obesity and television viewing in children and adolescents. *Pediatrics* 1985;75(5):807-12.
2. Andersen RE, Crespo CJ, Bartlett SJ, Cheskin LJ, Pratt M. Relationship of physical activity and television watching with body weight and level of fatness among children: results from the Third National Health and Nutrition Examination Survey. *JAMA* 1998;279(12):938-42.
3. Crespo CJ, Smit E, Troiano RP, Bartlett SJ, Macera CA, Andersen RE. Television watching, energy intake, and obesity in US children: results from the third National Health and Nutrition Examination Survey, 1988-1994. *Arch Pediatr Adolesc Med* 2001;155(3):360-5.
4. Janssen I, Katzmarzyk PT, Boyce WF, King MA, Pickett W. Overweight and obesity in Canadian adolescents and their associations with dietary habits and physical activity patterns. *J Adolesc Health* 2004;35(5):360-7.
5. Tremblay MS, Willms JD. Is the Canadian childhood obesity epidemic related to physical inactivity? *Int J Obes Relat Metab Disord* 2003;27(9):1100-5.
6. Brown JD, Witherspoon EM. The mass media and American adolescents' health. *J Adolesc Health* 2002;31(6 Suppl):153-70.
7. American Academy of Pediatrics: Children, adolescents, and television. *Pediatrics* 2001;107(2):423-6.
8. Canadian Paediatric Society. Healthy active living for children and youth. *Paediatrics & Child Health* 2002;7(5):339-45.

9. Impact of media use on children and youth. *Paediatrics & Child Health* 2003;8(5):301-6.
10. Roberts DF. Media and youth: access, exposure, and privatization. *J Adolesc Health* 2000;27(2 Suppl):8-14.
11. Currie C, Samdal O, Boyce W, Smith B. Health Behaviour in School-Aged Children: a World Health Organization Cross-National Study. Research Protocol for the 2001/02 Survey. Edinburgh, Scotland: Child and Adolescent Health Research Unit, University of Edinburgh; 2001 (http://www.hbsc.org/overview_studydesign.html).
12. Eisenmann JC, Bartee RT, Wang MQ. Physical activity, TV viewing, and weight in U.S. youth: 1999 Youth Risk Behavior Survey. *Obes Res* 2002;10(5):379-85.
13. Proctor MH, Moore LL, Gao D, et al. Television viewing and change in body fat from preschool to early adolescence: The Framingham Children's Study. *Int J Obes Relat Metab Disord* 2003;27(7):827-33.
14. DuRant RH, Baranowski T, Johnson M, Thompson WO. The relationship among television watching, physical activity, and body composition of young children. *Pediatrics* 1994;94(4 Pt 1):449-55.
15. Marshall SJ, Biddle SJ, Gorely T, Cameron N, Murdey I. Relationships between media use, body fatness and physical activity in children and youth: a meta-analysis. *Int J Obes Relat Metab Disord* 2004;28(10):1238-46.
16. Robinson TN, Hammer LD, Killen JD, et al. Does television viewing increase obesity and reduce physical activity? Cross-sectional and longitudinal analyses among adolescent girls. *Pediatrics* 1993;91(2):273-80.

17. Francis LA, Lee Y, Birch LL. Parental weight status and girls' television viewing, snacking, and body mass indexes. *Obes Res* 2003;11(1):143-51.
18. Robinson TN. Television viewing and childhood obesity. *Pediatr Clin North Am* 2001;48(4):1017-25.
19. Robinson TN. Reducing children's television viewing to prevent obesity: a randomized controlled trial. *JAMA* 1999;282(16):1561-7.
20. Gortmaker SL, Peterson K, Wiecha J, et al. Reducing obesity via a school-based interdisciplinary intervention among youth: Planet Health. *Arch Pediatr Adolesc Med* 1999;153(4):409-18.
21. Epstein LH, Paluch RA, Gordy CC, Dorn J. Decreasing sedentary behaviors in treating pediatric obesity. *Arch Pediatr Adolesc Med* 2000;154(3):220-6.

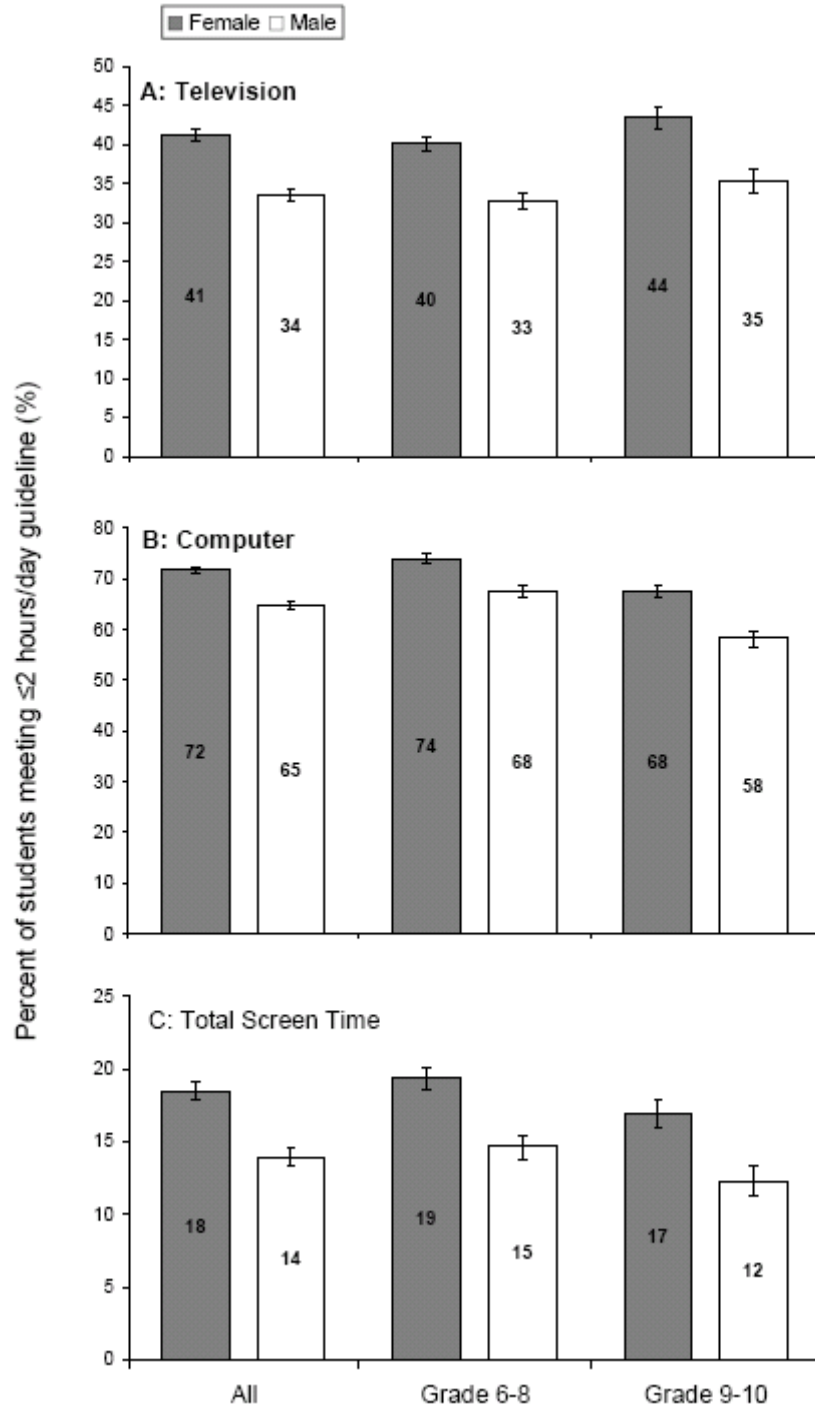
Table 1. Distribution of screen time variables according to gender and grade.

Type of screen time		Percentile				
		10 th	25 th	50 th	75 th	90 th
<i>Television (hours per day)</i>						
Females	All	0.71	1.29	2.29	3.57	4.86
	Grades 6-8	0.79	1.29	2.43	3.57	4.86
	Grades 9-10	0.71	1.29	2.29	3.43	4.57
Males	All	1.00	1.71	2.71	3.86	5.29
	Grades 6-8	1.00	1.71	2.71	4.00	5.57
	Grades 9-10	1.00	1.57	2.57	3.71	4.86
<i>Computer (hours per day)</i>						
Females	All	0.14	0.50	1.00	2.29	3.57
	Grades 6-8	0.14	0.50	1.00	2.29	3.29
	Grades 9-10	0.14	0.50	1.29	2.43	3.71
Males	All	0.00	0.50	1.29	2.57	4.29
	Grades 6-8	0.00	0.50	1.29	2.57	4.14
	Grades 9-10	0.14	0.64	1.57	3.29	4.86
<i>Total Screen Time (hours per day)</i>						
Females	All	1.50	2.46	3.71	5.50	7.29
	Grades 6-8	1.46	2.29	3.71	5.43	7.29
	Grades 9-10	1.57	2.50	3.79	5.57	7.29
Males	All	1.79	2.86	4.36	6.29	8.29
	Grades 6-8	1.71	2.79	4.29	6.14	8.29
	Grades 9-10	1.93	3.04	4.57	6.57	8.43

FIGURE CAPTION

Figure 1. Prevalence of students meeting the guideline of 2 hours a day or less of entertainment media time for television time (panel A), computer time (panel B) and total screen time (panel C). The error bars represent the 95% confidence intervals.

Figure 1



CHAPTER 8

Manuscript 6

Relationship Between Screen Time and Metabolic Syndrome in Adolescents

This manuscript is published in the *Journal of Public Health* 2008;30(2):153-160 and has been presented in a format consistent with the journal requirements.

Guideline component: This manuscript explores the volume component of the screen time guidelines by examining the dose-response relation between screen time and the metabolic syndrome. Current Canadian and American guidelines recommend 2 hours or less of screen time per day.

ABSTRACT

Background. The primary objective was to determine the dose-response relation between screen time (television + computer) and the metabolic syndrome (MetS) in adolescents.

Methods. The study sample included 1803 adolescents (12-19 years) from the 1999-2004 U.S. National Health and Nutrition Examination Surveys. Average daily screen time (combined television, computer, and video game use) was self-reported. MetS was defined according to adolescent criteria linked to the adult criteria of the National Cholesterol Education Program (≥ 3 of: high triglycerides, high fasting glucose, high waist circumference, high blood pressure, and low HDL-cholesterol).

Results. After adjustment for relevant covariates, the odds ratios (OR, 95% confidence intervals) for MetS increased in a dose-response manner ($P_{\text{trend}} < 0.01$) across ≤ 1 hr/d (1.00, referent), 2 hr/d (1.21, 0.54-2.73), 3 hr/d (2.16, 0.99-4.74), 4 hr/d (1.73, 0.72-4.17), and ≥ 5 hr/d (3.07, 1.48-6.34) screen time categories. Physical activity had a minimal impact on the relation between screen time and MetS.

Conclusions. Screen time was associated with an increased likelihood of MetS in a dose-dependent manner independent of physical activity. These findings suggest that lifestyle based public health interventions for youth should include a specific component aimed at reducing screen time.

INTRODUCTION

The positive relationship between television viewing and obesity in children and adolescents is well known.¹⁻⁶ Television viewing has also been linked to a number of other important public health issues in youth including violent and aggressive acts, initiation of early sexual behaviours, body self-image issues, and substance use and abuse.⁶ Excessive computer and video game use has been associated with many of the same health and social problems.⁶

The negative impact of excessive television and computer use on the health and well-being of children and youth prompted the American Academy of Pediatrics and the Canadian Paediatric Society to establish public health and clinical guidelines for screen time use (television + computer + video games). The guidelines recommend that children and adolescents limit screen time to no more than 2 hours per day.^{7,8} Although the influence of screen time on poor health was well established when the guidelines were developed, it is not clear how or why the 2 hour threshold was selected. Dose-response studies of screen time and health are required to verify the appropriateness of this threshold. Furthermore, from a physical health perspective, obesity was the primary outcome considered in the development of the screen time guidelines. There is a need to ascertain the connection between screen time and other pertinent outcomes such as the metabolic syndrome (MetS). MetS represents a clustering of cardiovascular disease and type 2 diabetes risk factors that predisposes one to several chronic diseases and premature mortality.⁹ Clinical criteria for MetS often include features such as abdominal obesity, high triglycerides, low HDL-cholesterol, high fasting glucose, and high blood pressure.⁹

Recent estimates suggest that 7.6% of American adolescents have the MetS,¹⁰ with a prevalence of over 30% in overweight and obese youth.¹¹

It is also not clear if the relationship between screen time and health is independent of other behaviours that may be associated with screen time, most notably physical activity participation. Clarification of the independent effect of screen time on health has important implications for the development of interventions aimed at decreasing sedentary behaviours and increasing physical activity (i.e., should the intervention focus be placed on one or both behaviours?). In a large sample of adolescents from the European Youth Heart Study, television viewing time was correlated to MetS components, but not the clustered cardiometabolic risk factor score, after adjustment for physical activity.¹² These results suggest that screen time itself may not be an independent predictor of obesity and other cardiometabolic risk factors. However, the European Youth Heart Study only considered television time and did not measure other important components of screen time such as computer and video game use.

The objectives of this study were to determine if screen time is related to MetS in adolescents, to examine the dose-response pattern of that relationship, and to determine if the relationship between MetS and screen time is independent of physical activity.

METHODS

The study sample consisted of a subgroup of subjects from the 1999-2000, 2001-2002, and 2003-2004 National Health and Nutrition Examination Surveys (NHANES). NHANES is a cross-sectional survey completed in the U.S. population and identified

subjects using a complex, stratified, multistage, probability sampling design.

Participation in the survey was voluntary. Written informed parental consent and child assent was obtained from participants under 18 years of age; written consent was obtained from participants 18 years and older. The protocol was approved by the National Center for Health Statistics. A more detailed description of the NHANES methodology is provided in Appendix B. The secondary analysis presented here was approved by the Queen's University Health Sciences Research Ethics Board.

The eligible NHANES sample for the present study included those aged 12-19 years who completed both the home interview and mobile exam centre (MEC) components of the survey. Only subjects with complete screen time, physical activity, demographic, dietary, anthropometric, blood pressure, and fasting blood measures were examined in the present study (n=1803). Compared to the total eligible NHANES sample in the same age range (n=6980), the study sample comprised a greater proportion of males (55.7 vs. 50.3%), a greater proportion of non-Hispanic whites (29.9 vs. 25.7%), and were slightly older (age 15.7 ± 2.2 vs. 15.4 ± 2.3 years).

Screen Time

Screen time included television, video, and computer game use, and was ascertained as part of the physical activity questionnaire, which was completed in the home interview or MEC depending on the survey round and age of the participant. Subjects reported the number of hours per typical day in the past 30 days that they watched television (including videos) and/or used a computer (including video games console) during their free time. Response categories included “none”, “less than 1 hour”, “1 hour”, “2 hours”, “3 hours”, “4 hours”, and “5 or more hours”. Screen time categories

of “none”, “less than 1 hour”, and “1 hour”, representing 24.2% of the study sample, were combined. All subjects in the 1999-2000 survey and those age 16-19 years in the 2001-2002 survey were asked about combined television, video, and computer use; whereas participants aged 12-15 years in the 2001-2002 survey and all participants in the 2003-2004 survey were asked separate questions regarding television/video use and computer use. Television/video and computer time were combined, when necessary, to create an overall screen time score. Only subjects 16-19 years were included from the 1999-2000 survey due to the inconsistency of the questions used to obtain screen time behaviours in 12-15 year olds, who reported on the previous day rather than the previous month.

Metabolic Syndrome

Metabolic Syndrome Criteria. Age- and gender-specific adolescent MetS criteria linked to the National Cholesterol Education Program Adult Treatment Panel III criteria were used to define MetS in this study.¹⁰ MetS was defined as having ≥ 3 of the following: high triglycerides, high fasting glucose, high waist circumference, high blood pressure, and low HDL-cholesterol. The age- and gender-specific thresholds for each MetS component were developed using growth curve modeling whereby the threshold for 12-19 year olds corresponds to the adult value at 20 years of age on the respective growth curve.¹⁰ Specifically, for each MetS component the gender-specific percentile score corresponding to the adult cut-point at exactly 20 years of age was determined. The percentile values for metabolic syndrome component were used within each 0.5 year age grouping to determine which subjects had each specific MetS component.¹⁰ For example, in adults a triglyceride value of 1.70 mmol/l is used to denote high risk values. This

corresponded to the 89th percentile at age 20 in males. Thus, the 89th percentile at each 0.5 year age grouping for 12-19 year old males was used to denote high triglyceride values. For a more detailed description of the method used to defined MetS the reader is referred to the paper by Jolliffe and Janssen.¹⁰

Measurement of Metabolic Syndrome Components. Subjects were seated and rested quietly for 5 minutes before 3 blood pressure measures were obtained on the right arm using a mercury sphygmomanometer. Systolic blood pressure was recorded at the first Korotkoff sound and diastolic blood pressure was the point of the last audible Korotkoff sound. Mean blood pressure values were used for all analyses. Waist circumference was measured to the nearest 0.1 cm at the level of the iliac crest at the end of a normal exhalation.¹³ Fasting blood samples were taken at the MEC examination. Only subjects who reported fasting for 8 or more hours were included in the analysis. Blood samples for HDL-cholesterol and triglycerides were analyzed at the Johns Hopkins University Lipoprotein Analytical Laboratory. HDL-cholesterol was analyzed using the heparin-manganese precipitation method. Triglycerides were measured enzymatically in a series of coupled reactions hydrolyzing triglycerides to produce glycerol.¹⁴ Samples for blood glucose were sent to University of Missouri for analysis and were assayed using a hexokinase enzyme method.¹⁴ A more detailed description of laboratory procedures are provided in the NHANES Laboratory Procedure Manual.¹⁴

Covariates

Covariates were selected a priori based on their relation between both the exposures and outcomes of interest as reported in previous studies.

Socio-demographic Information. Gender and race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, and other) were considered. The poverty-to-income ratio was used as a measure of socioeconomic status, and represents the ratio between family income to the family poverty threshold, which is based on family size and composition. Smoking status included never smokers, ever smokers, and non-responders. Covariates were selected to be consistent with literature and to control factors that may influence the relation between exposure and outcome.

Physical Activity. Self-reported participation in moderate-to-vigorous intensity physical activity was obtained during the home interview or MEC depending on the survey round and age of the participant. Subjects reported the frequency (number of times in past 30 days) and average duration (in minutes) per session for each moderate and vigorous intensity activity they participated in during the previous 30 days. Activities were selected from a list with the option to add additional activities. For each activity, a daily average was calculated by multiplying the frequency and duration of the activity, and dividing by 30. Total daily physical activity represents the sum of all activities. Physical activity categories were created using the following thresholds: 0-14 min/d, 15-29 min/d, 30-44 min/d, and ≥ 45 min/d. Categories were selected to provide meaningful groups for the interpretation of results. Because a limited number of subjects (10.6%) met physical activity guidelines¹⁵ of more than 60 minutes of moderate-to-vigorous physical activity per day, a separate category was not created for this physical activity level. In youth, questionnaire measures of physical activity are reliable and modestly correlated ($r=0.40$) with objective measures physical activity measures obtained

by accelerometer,¹⁶ although the questionnaire measures tend to over estimate physical activity levels.¹⁷

Dietary Measures. Subjects were queried and reported on type and amount of food and beverages consumed during the 24 hours prior to the MEC examination. Results of the dietary recall were used to estimate the percent of total calories from carbohydrates and fat. Subjects were separated into three groups for carbohydrate (<40% as low, 40-60% as moderate, >60% as high) and fat (<30% as low, 30-40% as moderate, >40% as high) consumption in accordance with dietary guidelines.¹⁸

Statistical Analysis

All analyses were completed using Intercooled Stata 7 (Strata Corporation, College Station, TX, USA) to take into account the sampling strategy and weighting of the NHANES survey. An alpha level of $p < 0.05$ represented statistical significance.

A 'yes' or 'no' binary variable for MetS was used as the dependent variable for the statistical analyses. A χ^2 test was used to compare the prevalence of MetS across screen time categories. A sample of χ^2 output is presented in Appendix H. We then performed logistic regression models to determine whether categories of screen time, with the ≤ 1 hr/day screen time category serving as the reference group (odds ratio = 1.00), and physical activity, with ≥ 45 min/day serving as the reference group, predicted MetS. Three models (basic, intermediate, and fully adjusted) were considered in the screen time and physical activity logistic regression analyses. The basic models considered the bivariate relation between the screen time or physical activity measure with MetS. The intermediate models considered the relation between the screen time or physical activity measure with MetS after controlling for covariates. The fully adjusted

model included both screen time and physical activity measures and controlling for the covariates. A sample of a logistic regression output is presented in Appendix J. The trend of association across categories of screen time and physical activity were also tested by repeating the analyses and including the screen time and/or physical activity categories as continuous variables (presented as P_{trend}).

RESULTS

A total of 1803 subjects (1005 males, 798 females) aged 12-19 years from the 1999-2000, 2001-2002, and 2003-2004 NHANES surveys were included in the analyses. Subject characteristics are presented in Table 1. Only 24.2% of subjects reported screen time values of 2 hours or less per day and met the public health screen time recommendation. The prevalence of MetS was 5.9% and did not differ between males and females. Mean values for the individual MetS component risk factors are also presented in Table 1.

As illustrated in Figure 1, the prevalence of MetS increased ($P=0.03$) as screen time increased from a low of 3.7% in the ≤ 1 hr/d screen time group to a high of 8.4% in the ≥ 5 hr/d screen time group. The results of the logistic regression analyses examining the relation between screen time and MetS are presented in Table 2. After controlling for the covariates (intermediate model), there was a linear trend for an increased odd ratio for the MetS across screen time groups ($P_{\text{trend}}=0.005$). In comparison to youth in the ≤ 1 hr/d screen time group, youth in the ≥ 5 hr/d screen time group were three times more likely to have MetS. The inclusion of physical activity as a covariate in the regression analysis

(fully adjusted model) had little influence on the relationship between MetS and screen time (Table 2).

Although the pattern of results shown in Table 3 suggests that physical activity was negatively related to MetS, such that physically inactive youth were more likely to have MetS than the most active youth, the relation between physical activity and MetS did not reach statistical significance in either the basic or intermediate models. The inclusion of screen time as a covariate in the regression model had little influence on the relation between physical activity and MetS (Table 3, fully adjusted model).

DISCUSSION

Main findings of this study

The primary finding was that the likelihood of having the MetS increased in a gradient dose-response manner as daily screen time hours increased, irrespective of physical activity level. Adolescents reporting screen times of ≥ 3 hours/day were approximately two to threefold more likely to have MetS than were adolescents with daily screen time levels of one hour or less.

What is already known on this topic

Screen time has previously been linked to a number of pediatric health determinants and outcomes including obesity and body-image issues, violent and aggressive behaviours, early sexual behaviours, and substance use and abuse.⁶ The results presented here for MetS are consistent with the consensus that excessive screen time negatively impacts the health and well-being of youth. The strong relation between excessive screen time and MetS is particularly troubling given that: 1) approximately

75% of the adolescent participants in this study had screen time levels of at least 2 hours per day; 2) MetS and its component risk factors tend to persist from adolescence into adulthood^{19,20}; 3) most chronic diseases, such as cardiovascular disease, are progressive conditions that start to develop in childhood^{21,22}; and 4) in adult populations MetS is a proven risk factor for type 2 diabetes,^{23,24} cardiovascular disease,²³⁻²⁵ and all-cause mortality.^{23,25} Based on these observations, the overall impact of excessive screen time in youth on MetS and resultant health outcomes is likely quite substantive at the population level.

What this study adds

To our knowledge the present study was the first to examine the dose-response nature of the relation between screen time and health. We observed a positive relation between screen time and MetS, which emphasizes the negative impact of increasing screen time across the continuum. However, our results suggest that the public health recommendation of no more than 2 hours of screen time per day^{7,8} may be somewhat restrictive, at least as the MetS is concerned. The likelihood of having MetS was only increased by 8% in the 2 hr/d screen time group, an amount that was far from reaching statistical relevance. However, once a screen time level of 3 hr/d was achieved, the likelihood of the MetS was increased by about twofold, and was clinically meaningful and of borderline significance (P=0.05).

The study also sought to determine if the relation between screen time and MetS was independent of any potentially confounding influence of physical activity. Our observation that physical activity had little or no impact on the relation between screen time and MetS is consistent with previous findings that physical activity and screen time

behaviours are poorly or unrelated in youth.^{4, 12, 26} The fact that screen time was related to MetS independent of moderate-to-vigorous intensity physical activity raises questions about the mechanism by which screen time influences MetS. One possible explanation is that only moderate-to-vigorous intensity physical activity was measured, and the lower intensity activities that were not captured in the NHANES survey were having some unmeasured effects. Another possible explanation is that screen time is more ‘sedentary’ than other sedentary behaviours (e.g., reading, talking on the phone). One study reported that energy expenditure in children and youth is lower while they are watching television than it is while they are at rest.²⁷ Another study found an inverse relation between resting energy expenditure and weekly hours of television, however, the same study reported no differences in energy expenditure while resting, watching television, and story listening.²⁸ A final explanation is that the time spent watching television is associated with poor dietary habits such as increased consumption of soft drinks and sweets, and decreased consumption of fruits and vegetables.²⁹ We controlled for the macronutrient intake of fat and carbohydrates in our analyses, which suggests that the influence of television on dietary habits may not account for the influence of screen time on MetS.

The finding that screen time was an independent predictor of MetS in adolescents differs from a report based on the European Youth Heart Study in which no relationship existed between television time and cardiometabolic risk factors after adjusting for physical activity level.¹² Several methodological differences likely account for the discrepancy in results. The European Youth Heart Study only measured television time, while the combined index of television and computer use employed in our study provided a more comprehensive measure of screen time behaviours. Conversely, our study relied

on a self-report measure of physical activity, which is subject to considerable recall bias in adolescents,³⁰ while the European Youth Heart Study used accelerometers to obtain an objective measure of physical activity. Thus, the measures used in our study were better suited to detect effects of screen time, while the measures used in the European Youth Heart Study were better suited to detect effects of physical activity, which is exactly what these two studies found. Finally, the European Youth Heart Study examined a cardiometabolic risk score created by summing age-adjusted z-scores for blood pressure, skinfolds, glucose, insulin, HDL-C, and triglycerides. In comparison, we used adolescent National Cholesterol Education Program criteria for MetS that relied on measures of waist circumference, blood pressure, HDL-C, triglycerides, and glucose.¹⁰

Strengths and limitations

Key strengths to this study include the use of a representative study sample and an age-appropriate measure of MetS for adolescents. The primary study limitation was the cross-sectional and observational nature, which prevents us from making causal inferences about the relation between screen time and MetS. The other main limitation was the self-reported measures of screen time and physical activity. Self-reported measures tend to underestimate socially undesirable behaviours (e.g., screen time) and over estimate socially desirable behaviour (e.g., physical activity).¹⁷ Although socially undesirable activities such as screen time are typically under reported,¹⁷ a previous study in youth found that television time was only underestimated by 0.09 hours per week.³¹ Furthermore, simple questionnaire measures of television use, such as those obtained in NHANES, are correlated ($r=0.47$) with television time measured by a detailed log.³¹ However, because the NHANES screen time question did not distinguish between days,

the validity of the screen time measure may have been affected since screen time has been shown to differ between weekdays and weekend days.³¹

Conclusions

High screen time was associated with an increased likelihood of MetS independent of physical activity, diet, and other important covariates. The results suggested that the screen time guidelines of no more than 2 hours per day may be somewhat restrictive with respect to MetS risk, as the odds ratio for MetS did not increase notably until 3 hours of screen time per day. The findings of this study also suggest that public health interventions that target health behaviours in adolescents should include a specific component(s) aimed at reducing screen time. This observation has important public health and clinical implications and emphasizes the importance of targeting both screen time and physical activity behaviours for improving the health of youngsters. Specifically, interventions that are successful at increasing the physical activity level of young people will not necessarily be successful at simultaneously decreasing their screen time.^{32, 33} And because the relation between screen time and MetS appear to be independent of physical activity, improving physical activity while maintaining screen time levels is likely far from optimal. Additional studies, particularly intervention studies, are needed to verify this contention.

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References

1. Tremblay MS, Willms JD. Is the Canadian childhood obesity epidemic related to physical inactivity? *Int J Obes Relat Metab Disord* 2003;27(9):1100-5.
2. Dietz WH, Jr., Gortmaker SL. Do we fatten our children at the television set? Obesity and television viewing in children and adolescents. *Pediatrics* 1985;75(5):807-12.
3. Janssen I, Katzmarzyk PT, Boyce WF, King MA, Pickett W. Overweight and obesity in Canadian adolescents and their associations with dietary habits and physical activity patterns. *J Adolesc Health* 2004;35(5):360-7.
4. Andersen RE, Crespo CJ, Bartlett SJ, Cheskin LJ, Pratt M. Relationship of physical activity and television watching with body weight and level of fatness among children: results from the Third National Health and Nutrition Examination Survey. *JAMA* 1998;279(12):938-42.
5. Crespo CJ, Smit E, Troiano RP, Bartlett SJ, Macera CA, Andersen RE. Television watching, energy intake, and obesity in US children: results from the third National Health and Nutrition Examination Survey, 1988-1994. *Arch Pediatr Adolesc Med* 2001;155(3):360-5.
6. Brown JD, Witherspoon EM. The mass media and American adolescents' health. *J Adolesc Health* 2002;31(6 Suppl):153-70.
7. American Academy of Pediatrics: Children, adolescents, and television. *Pediatrics* 2001;107(2):423-6.
8. Impact of media use on children and youth. *Paediatrics & Child Health* 2003;8(5):301-6.

9. Ardern CI, Janssen I. Metabolic syndrome and its association with morbidity and mortality. *Appl Physiol Nutr Metab* 2007;32(1):33-45.
10. Jolliffe CJ, Janssen I. Development of age-specific adolescent metabolic syndrome criteria that are linked to the Adult Treatment Panel III and International Diabetes Federation criteria. *J Am Coll Cardiol* 2007;49(8):891-8.
11. de Ferranti SD, Gauvreau K, Ludwig DS, Neufeld EJ, Newburger JW, Rifai N. Prevalence of the Metabolic Syndrome in American Adolescents: Findings From the Third National Health and Nutrition Examination Survey. *Circulation* 2004;110(16):2494-7.
12. Ekelund U, Brage S, Froberg K, et al. TV viewing and physical activity are independently associated with metabolic risk in children: the European Youth Heart Study. *PLoS Med* 2006;3(12):e488.
13. U.S. Department of Health and Human Services and National Center for Health Statistics. National Health and Nutrition Examination Survey Anthropometry Procedure Manual. In: Department of Health and Human Services, Centers for Disease Control and Prevention, Hyattsville, MD: U.S.; 2004.
14. U.S. Department of Health and Human Services and National Center for Health Statistics. National Health and Nutrition Examination Survey Laboratory Procedure Manual. In: Prevention. CfDcA, ed.: Department of Health and Human Services, Centers for Disease Control and Prevention, Hyattsville, MD: U.S.; 2004.
15. Strong WB, Malina RM, Blimkie CJ, et al. Evidence based physical activity for school-age youth. *J Pediatr* 2005;146(6):732-7.

16. Prochaska JJ, Sallis JF, Long B. A Physical Activity Screening Measure for Use With Adolescents in Primary Care. *Arch Pediatr Adolesc Med* 2001;155(5):554-9.
17. Sirard JR, Pate RR. Physical activity assessment in children and adolescents. *Sports Med* 2001;31(6):439-54.
18. U.S. Department of Health and Human Services, U.S. Department of Agriculture. *Dietary Guidelines for Americans, 2005*. In. 6th ed. Washington, DC: U.S. Government Printing Office; January, 2005.
19. Katzmarzyk PT, Perusse L, Malina RM, Bergeron J, Despres JP, Bouchard C. Stability of indicators of the metabolic syndrome from childhood and adolescence to young adulthood: the Quebec Family Study. *J Clin Epidemiol* 2001;54(2):190-5.
20. Eisenmann JC, Welk GJ, Wickel EE, Blair SN. Stability of variables associated with the metabolic syndrome from adolescence to adulthood: the Aerobics Center Longitudinal Study. *Am J Hum Biol* 2004;16(6):690-6.
21. Berenson GS, Srinivasan SR, Bao W, Newman WP, 3rd, Tracy RE, Wattigney WA. Association between multiple cardiovascular risk factors and atherosclerosis in children and young adults. The Bogalusa Heart Study. *N Engl J Med* 1998;338(23):1650-6.
22. Berenson GS, Wattigney WA, Tracy RE, et al. Atherosclerosis of the aorta and coronary arteries and cardiovascular risk factors in persons aged 6 to 30 years and studied at necropsy (The Bogalusa Heart Study). *Am J Cardiol* 1992;70(9):851-8.
23. Ford ES. Risks for all-cause mortality, cardiovascular disease, and diabetes associated with the metabolic syndrome: a summary of the evidence. *Diabetes Care* 2005;28(7):1769-78.

24. Lorenzo C, Williams K, Hunt KJ, Haffner SM. The National Cholesterol Education Program-Adult Treatment Panel III, International Diabetes Federation, and World Health Organization Definitions of the Metabolic Syndrome as Predictors of Incident Cardiovascular Disease and Diabetes. *Diabetes Care* 2007;30(1):8-13.
25. Lakka H-M, Laaksonen DE, Lakka TA, et al. The Metabolic Syndrome and Total and Cardiovascular Disease Mortality in Middle-aged Men. *JAMA* 2002;288(21):2709-16.
26. Berkey CS, Rockett HR, Gillman MW, Colditz GA. One-year changes in activity and in inactivity among 10- to 15-year-old boys and girls: relationship to change in body mass index. *Pediatrics* 2003;111(4 Pt 1):836-43.
27. Klesges RC, Shelton ML, Klesges LM. Effects of television on metabolic rate: potential implications for childhood obesity. *Pediatrics* 1993;91(2):281-6.
28. Cooper TV, Klesges LM, Debon M, Klesges RC, Shelton ML. An assessment of obese and non obese girls' metabolic rate during television viewing, reading, and resting. *Eat Behav* 2006;7(2):105-14.
29. Vereecken CA, Todd J, Roberts C, Mulvihill C, Maes L. Television viewing behaviour and associations with food habits in different countries. *Public Health Nutr* 2006;9(2):244-50.
30. Goran MI. Measurement issues related to studies of childhood obesity: assessment of body composition, body fat distribution, physical activity, and food intake. *Pediatrics* 1998;101(3 Pt 2):505-18.

31. Schmitz KH, Harnack L, Fulton JE, et al. Reliability and validity of a brief questionnaire to assess television viewing and computer use by middle school children. *J Sch Health* 2004;74(9):370-7.
32. Gortmaker SL, Peterson K, Wiecha J, et al. Reducing obesity via a school-based interdisciplinary intervention among youth: Planet Health. *Arch Pediatr Adolesc Med* 1999;153(4):409-18.
33. Robinson TN. Reducing children's television viewing to prevent obesity: a randomized controlled trial. *JAMA* 1999;282(16):1561-7.

Table 1. Subject characteristics.

	Males (n=1005)	Females (n=798)
Age (years)	15.9 ± 2.2	15.6 ± 2.3
Race/ethnicity		
Non-Hispanic white	29.0%	31.1%
Non-Hispanic black	32.1%	26.1%
Hispanic/Hispanic-Mexican	33.7%	37.8%
Other	5.2%	5.0%
Screen time (hr/d)	3.1 ± 2.0	2.9 ± 2.0
Moderate-to-vigorous physical activity (min/d)	28.4 ± 50.9	19.1 ± 30.2
Metabolic Syndrome Component		
Waist circumference, cm	81.7 ± 14.8	80.7 ± 14.0
HDL-cholesterol, mmol/L	1.28 ± 0.31	1.40 ± 0.33
Triglycerides, mmol/L	1.02 ± 0.86	0.94 ± 0.53
Fasting glucose, mmol/L	5.19 ± 0.72	4.94 ± 0.42
Systolic blood pressure, mmHg	112.8 ± 10.4	106.2 ± 9.3
Diastolic blood pressure, mmHg	61.2 ± 11.8	62.8 ± 9.3

Data presented as prevalences (%) or mean ± standard deviation.

Table 2. Odds ratios for the metabolic syndrome based on daily screen time

<i>Daily Screen Time</i>	<i>Unadjusted model</i>	<i>Intermediate model</i>	<i>Fully Adjusted Model</i>
≤1 hour	1.00	1.00	1.00
2 hours	1.19 (0.54-2.66)	1.08 (0.45-2.57)	1.08 (0.45-2.55)
3 hours	2.05 (0.92-4.55)	2.14 (1.00-4.58) ^a	2.10 (0.99-4.43)
4 hours	1.76 (0.76-4.07)	1.72 (0.67-4.14)	1.73 (0.68-4.39)
≥5 hours	2.91 (1.42-5.95) ^a	3.00 (1.42-6.33) ^b	2.79 (1.32-5.87) ^b
	P _{trend} = 0.006	P _{trend} = 0.005	P _{trend} = 0.007

Data presented as odds ratios (95% confidence intervals). The intermediate model was adjusted for sex, age, race/ethnicity, socio-economic status, smoking status, and dietary measures. The fully adjusted model was adjusted the sex, age, race/ethnicity, the poverty-to-income ratio, smoking status, dietary measures, and physical activity.

^aP < 0.05, ^bP<0.01 compared to ≤1 hour screen time group

Table 3. Odds ratios for the metabolic syndrome based on level of physical activity

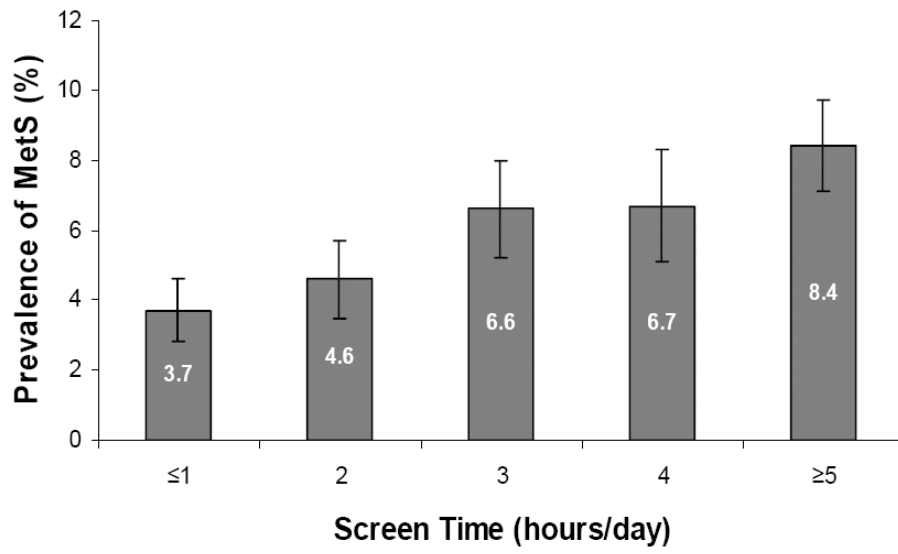
<i>Daily Physical Activity</i>	<i>Unadjusted model</i>	<i>Intermediate model</i>	<i>Fully Adjusted Model</i>
≥45 min	1.00	1.00	1.00
30 to 44 min	1.62 (0.44-5.93)	1.94 (0.50-7.50)	1.75 (0.43-7.05)
15 to 29 min	1.28 (0.40-4.11)	1.36 (0.42-4.32)	1.29 (0.40-4.16)
0 to 14 min	2.04 (0.80-5.21)	2.20 (0.86-5.62)	1.87 (0.71-4.95)
	P _{trend} = 0.16	P _{trend} = 0.13	P _{trend} = 0.22

Data presented as odds ratios (95% confidence intervals). The intermediate model was adjusted for sex, age, race/ethnicity, socio-economic status, smoking status, and dietary measures. The fully adjusted model was adjusted for sex, age, race/ethnicity, the poverty-to-income ratio, smoking status, dietary measures, and screen time.

FIGURE CAPTION

Figure 1. Prevalence (%) of the metabolic syndrome according to screen time category. The error bars represent the 95% confidence intervals.

Figure 1



CHAPTER 9

GENERAL DISCUSSION AND CONCLUSION

9.1 Summary of Key Findings

Findings from each manuscript provide information relevant to a specific component of the physical activity and/or screen time public health guidelines for children and youth.

The first manuscript explored the volume component of the physical activity guidelines. A curvilinear dose-response relation was observed between physical activity and hypertension. There was a large decrease in the likelihood of hypertension with 30 minutes of moderate-to-vigorous intensity physical activity per day, with only a modest added benefit observed when comparing 30 and 60 minutes. These results suggest that the recommendation within the Canadian Physical Activity guidelines to increase daily physical activity by 90 minutes^{1,2} and even the 60 minutes of daily physical activity recommended in the Evidence Based Physical Activity guidelines³ may need to be re-considered. That is, while a high volume of physical activity may be ideal, tremendous health benefits appear to be achieved at much lower levels of physical activity.

Therefore, making recommendations for a *minimal* amount of physical activity, that is far lower than the *ideal* volume of 90 or 60 minute/day, may be worth considering. Setting a minimal threshold for physical activity may be particularly useful for sedentary children and youth who may be discouraged and intimidated by the volume of physical activity recommended in current guidelines.

The second manuscript examined the influence of the intensity of physical activity on adiposity in youth. Moderate-to-vigorous intensity physical activity predicted adiposity after controlling for the total volume of physical activity. However, vigorous intensity activity did not predict adiposity after controlling for the volume of moderate-to-vigorous physical activity. The findings from this study support the recommendation of the Evidence Based Physical Activity guidelines to focus on moderate-to-vigorous intensity physical activity.³ This finding also suggests that the stipulation in the Canadian Physical Activity guidelines to increase vigorous intensity physical activity by 30 minutes per day^{1,2} may not be necessary, at least with respect to adiposity.

Manuscript three explored whether the manner in which physical activity is accumulated throughout the day – either sporadically or in periodic bouts – had an influence on adiposity status. Both short (5-9 minute) and medium-to-long (≥ 10 minute) bouts of physical activity were found to predict adiposity above and beyond that predicted by the total volume of physical activity. This observation provides evidence to support the recommendation within the Canadian Physical Activity guidelines that physical activity should be accumulated in bouts of at least 5 to 10 minutes in duration.^{1,2} This finding also infers that any revised or newly developed set of physical activity guidelines for youth should consider including a stipulation about accruing physical activity in bouts. Given that this was the first study to explore the independent effects of bouts of activity on health in youngsters, additional research is clearly warranted.

The fourth manuscript provided a detailed examination of the relation between physical activity and screen time by considering different forms of physical activity (e.g., structured and unstructured), different physical activity environments (e.g., school and

outside of school), and different types of screen time (e.g., television, computer). In general, no relations were found between the various physical activity and screen time measures. Thus, although it is commonly believed that targeting screen time behaviours will also impact physical activity participation, this is not supported by the findings presented in this thesis. It would therefore appear that intervening on both screen time and physical activity, as recommended in the Canadian Physical Activity guidelines,^{1, 2} is necessary.

Manuscript five was a short descriptive paper that determined the proportion of Canadian youth meeting screen time guidelines of no more than 2 hours per day.^{4, 5} Less than 20% of Canadian youth in grades 6 to 10 were found to meet the screen time guidelines, regardless of age and sex. Clearly, these findings indicate that effective public health interventions are needed to reduce screen time within Canadian youth.

The final manuscript focused on the volume of screen time as it related to the metabolic syndrome, a clustering of cardiometabolic risk factors. A dose-response relation was observed between screen time and the metabolic syndrome such that the odds of having the metabolic syndrome increased as screen time increased. Although watching the recommended 2 hours of screen time per day was not associated with an increased likelihood of the metabolic syndrome relative to little or no screen time, youth who spent 3 hours/day in front of the screen had a two-fold increased odds of the metabolic syndrome. Five daily hours of screen time increased the odds three-fold. The findings from this study indicate that, at least with respect to cardiometabolic risk, the American Association of Pediatrics and Canadian Paediatric Society recommendation of no more than two hours a day of screen time^{4, 5} may be too restrictive.

9.2 Strengths of the Thesis

The studies contained within this thesis were based on large and nationally representative samples of Canadian (HBSC) and American (NHANES) school-aged youth. Thus, the findings presented in this thesis can be generalized to the greater population.

Objective measures of physical activity (accelerometers) were employed in three of the studies. Accelerometers provide a measure of the duration and intensity of physical activity under free-living conditions.^{6,7} As well, several important cardiometabolic risk factors were considered in these studies including hypertension, obesity, and the metabolic syndrome. The advanced statistical modeling approaches employed in this thesis, such as the methods used to model the dose-response relation between physical activity and blood pressure, was also a strength when compared to the modeling approaches employed in other studies of physical activity and health in the paediatric population.

9.3 Limitations of the Thesis

Several limitations warrant consideration. The cross-sectional and observational nature of NHANES and HBSC prevents any causal inferences from being made regarding the relation between the exposures and outcomes explored. Additionally, because NHANES is a nationally representative sample of Americans, the results may not be generalizable to Canadians.

Accelerometers, used to assess physical activity in several of the studies, do not capture all physical activities because the devices cannot get wet (e.g., will not measure

water based activities) and only measure vertical displacement of the body (e.g., do not fully capture upper body activities or cycling). Several of the other studies in the thesis measured physical activity and screen time using self-reported questionnaires. Due to the limitations of the measures employed in the thesis, there may have been some non-differential misclassification bias that could have decreased the magnitude of the associations between exposures (e.g., physical activity and screen time) and outcomes (e.g., adiposity) examined.

9.4 Future Research Directions

Further research is needed to explore the relation between volume and intensity of physical activity, bouts of physical activity, and screen time with other physical health outcomes such as blood lipids and bone density, and psychological health outcomes such as depression and anxiety. As well, the ideal frequency of physical activity participation in children and youth is unknown. For instance, the Evidence Based Physical Activity guidelines recommend 60 minutes of physical activity on a *daily* basis. However, if a child were to miss a day of activity (e.g., illness, travelling) would it make any difference if they were to make up that lost physical activity time on a subsequent day? Similarly, it is not clear if screen time guidelines need to be met every day (e.g., a single movie could last over 2 hours) or if averaging out screen time over several days or weeks would be more appropriate.

Comparable objective measures of physical activity and cardiometabolic health that were obtained in NHANES are currently being collected by Statistics Canada in the Canadian Health Measures Survey. The relations between physical activity and health

explored in the studies included in this thesis should be completed with the Canadian Health Measures Survey data to confirm the observed relations in Canadian youngsters.

9.5 Public Health Implications

Individually, each of the 6 manuscripts contained in this thesis provides a piece of information regarding a particular component of the physical activity and/or screen time guidelines, and as such has a clear public health implication. Collectively, the results from the 6 thesis manuscripts contribute unique findings to the body of literature that would be reviewed as part of the process used in developing and revise evidence-based physical activity and/or screen time guidelines for school-aged children and youth. While some of the findings made in this thesis support some of the recommendations made within the various sets of guidelines, other findings of this thesis debunk some of the fundamental albeit unsubstantiated recommendations contained within these guidelines. Therefore, as suggested in a recent review of the Canadian Physical Activity guidelines for children and youth,⁸ many of the current physical activity and screen time guidelines need to be updated.

9.6 Conclusion

In conclusion, the findings of this thesis provide novel insights into the relations between physical activity, sedentary behaviour, and cardiometabolic health. Specifically, the results of these manuscripts suggest that youth should participate in at least 30 minutes of moderate-to-vigorous intensity physical activity on a daily basis, with at least one bout lasting between 5 and 9 minutes and one bout lasting 10 minutes or longer. As

well, physical activity guidelines should include a screen time component that recommends limiting screen time to less than 3 hours per day. It is hoped that these findings will provide useful information that can be used in the development and modification of evidence-based physical activity and screen time guidelines for school-aged children and youth.

References

1. Health Canada and Canadian Society for Exercise Physiology. Canada's Physical Activity Guide to Healthy Active Living: Family Guide to Physical Activity for Youth 6-9 Years of Age. In. Ottawa, ON: Minister of Health; 2002.
2. Health Canada and the Canadian Society for Exercise Physiology. Canada's Physical Activity Guide to Healthy Active Living: Family Guide to Physical Activity for Youth 10-14 Years of Age. In. Ottawa, ON: Minister of Health; 2002.
3. Strong WB, Malina RM, Blimkie CJ, et al. Evidence based physical activity for school-age youth. *J Pediatr* 2005;146(6):732-7.
4. Impact of media use on children and youth. *Paediatrics & Child Health* 2003;8(5):301-6.
5. American Academy of Pediatrics: Children, adolescents, and television. *Pediatrics* 2001;107(2):423-6.
6. Trost SG, Pate RR, Freedson PS, Sallis JF, Taylor WC. Using objective physical activity measures with youth: how many days of monitoring are needed? *Med Sci Sports Exerc* 2000;32(2):426-31.
7. Van Coevering P, Harnack L, Schmitz K, Fulton JE, Galuska DA, Gao S. Feasibility of using accelerometers to measure physical activity in young adolescents. *Med Sci Sports Exerc* 2005;37(5):867-71.
8. Janssen I. Physical activity guidelines for children and youth. *Applied Physiology Nutrition and Metabolism* 2007;32(2E):S109-S21.

APPENDIX A

List of Abbreviations

LIST OF ABBREVIATIONS

BMI	body mass index
BP	blood pressure
CCHS	Canadian Community Health Survey
CI	confidence interval
DBP	diastolic blood pressure
HBSC	Health Behaviour in School-Aged Children Survey
HDL-C	high density lipoprotein cholesterol
MEC	mobile examination centre
MetS	metabolic syndrome
METs	metabolic equivalents
NHANES	National Health and Nutrition Examination Survey
PA	physical activity
SBP	systolic blood pressure
WC	waist circumference

APPENDIX B

National Health and Nutrition Examination Survey (NHANES) Methodology

Background and Purpose

The overall goal of NHANES is to monitor the health of the American population; a more comprehensive list of goals is available on the survey website (www.cdc.gov/nchs/tutorials/Nhanes/SurveyOrientation/SurveyOverview/Info1.htm). The survey started back in 1960 as the National Health Examination Survey and has evolved into its current form. In 1999 the National Health and Nutrition Examination Survey changed from a periodic survey including large data set from multiple years of sampling to the continuous format with data released in two year increments (e.g., 1999-2000, 2001-2002, etc.). The data used in this thesis is based on the continuous NHANES survey.

There are two components to the survey, the home examination and mobile examination centre (MEC) exam. The home examination portion consists primarily of questionnaire based information (e.g., demographic information, lifestyle). Appointments for the MEC component are booked during the home examination. Physical health measures are obtained during the MEC (e.g., blood samples, blood pressure, anthropometry).

Survey Design

A complex, multi-stage, probability sampling design was used to identify possible participants in each of the NHANES cycles. Counties in the United States were used as the Primary Sampling Unit (PSU). For the 1999 and 2001 survey years, the PSU were obtained from 1995 National Health Interview Survey. Starting in 2002 the counties were identified using information from the 2000 United States census. In 1999 only 12 PSUs were visited, while 15 PSUs were visited each starting in 2000. Each PSU is

broken down into segments (e.g., city blocks), and there is random sampling of the homes within each segment. Individual homes are randomly selected for participation.

Each year the goal is to obtain measures on approximately 5000 individuals. Of those identified, between 79.3-81.9% participated in the home examination component, and between 75.6-79.6% participated in the MEC component. Certain segments of the population were oversampled; these include adolescents aged 12-19 years, persons aged ≥ 60 years, low income white, African American, and Mexican Americans.

Oversampling was used to ensure adequate numbers of individuals to improve estimates of health status indicators in these segments of the population.

All participants are given a sample weight indicating how representative they are of the population. The 2001-2002 and later cycles are based on the 2000 census; however, this information was not available for the 1999-2000 cycles and therefore sample weights differ. There are 2 year and 4 year sample weight for the 1999-2000 and 2001-2002 cycles to facilitate combining of these, and subsequent, cycles of the survey. Additionally, there are separate sample weights for each cycle depending on whether home examination or MEC data is used to take into account the differences in participation in these portions of the survey. Separate sample weights are also given when outcomes were only obtained on a portion of the MEC sample (e.g., morning subsample with fasting blood measures). All sample weights take into consideration the oversampling of certain segments of the population, and are adjusted for non-response to permit the calculation of unbiased national estimates.

Data

The NHANES public access data is located on the NHANES website (www.cdc.gov/nchs/nhanes.htm), and organized by cycle (e.g., 2001-2002) and collection method (demographic, laboratory, examination, or questionnaire). There are separate component data files for groups of variables, for example the variables for height and weight are found in the “Body Measurements” file (bmx_b.xpt). All files are Statistical Analysis Software (SAS) Xport Transport files and are specific to the year of measurement (e.g., the “_b” in the file name listed in the previous sentence indicates that this file is from the 2001-2002 cycle of NHANES).

Data files, along with corresponding documentation, can be downloaded from the website. All data files include the unique participant identifier numbers (variable name: “seqn”) permitting files to be merged into a data single file that includes all of the variables of interest for each participant. Files from the same cycle and from different cycles can be combined, and for this thesis this step was performed using SAS.

Limitations

The main limitation of NHANES is the cross-sectional design of the survey. Only associations between exposure and outcomes can be examined, and not cause and effect relations. Therefore, any observed associations are only suggestive of relations that require further studies to determine whether the exposure preceded the outcome in such a fashion (e.g., sufficient magnitude) to infer causality.

APPENDIX C

Health Behaviour in School-aged Children Survey (HBSC) Methodology

Overview of Survey Design and Sampling Strategy

The *Health Behaviour in School-Aged Children* survey (HBSC) is a cross-national survey completed every four years with the first survey completed in 1983/84. Researchers from several European countries initiated the survey to gain a better understanding of health behaviours and health indicators in the adolescent population; the survey later gained support from the World Health Organization. In the inaugural year four countries (Finland, Norway, United Kingdom and Austria) participated in the cross-sectional survey, but it has continuously expanded and the most recent survey conducted in 2005/06 included 41 industrialized countries (39 from Europe, Canada, and the United States). Two manuscripts within this thesis (Manuscript #4 and Manuscript #5) were based on the Canadian records from the 2001/02 HBSC.

A total 7266 youth completed the questionnaire in the Canadian 2001/02 HBSC survey representing 74.2% of eligible students invited to participate. The demographic profile of the participating students was representative of Canadians in the same age range. Overall, the distribution of the students sampled as part of the Canadian HBSC in 2001/02 reflects the distribution of students in grades 6 to 10 (reflecting ages 10-16 years). Samples were selected to represent distributions of schools by size, location, language, and religion and in such a way as to be self-weighting.¹ The sample was designed using a cluster design with the school class being the basic cluster. Schools were weighted based on the number of eligible classes with each class having the same likelihood of being selected. In schools where a class was randomly selected, classes in the other target age groups were also randomly selected to minimize the number of

schools required for participation. A total of 175 schools from across Canada's 10 provinces participated in the 2001/02 HBSC.

The HBSC survey itself consisted of a classroom based questionnaire administered during school time. All surveys include a core set of questions that are supplemented with additional focus questions to gain further information on specific issues.¹ The core information includes background (e.g., age, sex), health behaviour (e.g., alcohol use, eating patterns), health outcomes (e.g., self-reported health), individual and social resources (e.g., family support).¹ The Canadian data were collected from January to May of 2002.

The Canadian HBSC was approved by the Queen's University General Research Ethics Board. Consent was obtained from the participating school boards, individual schools, parents, and students. Student participation was voluntary.

Limitations of Survey

Some limitations of the HBSC warrant mentioning. The primary limitation is the cross-sectional nature of the survey, which only permits associations between exposures and outcomes to be examined, and not cause and effect relations, since the temporal sequence cannot be established. The other main limitation of the HBSC is that data was obtained, in entirety, from a self-report questionnaire which is subject to recall bias and social desirability bias. Factors such as peer interaction while completing the questionnaire may have also influenced responses by students.

Reference

1. Currie C, Samdal O, Boyce W, Smith B. Health Behaviour in School-Aged Children: a World Health Organization Cross-National Study. Research Protocol for the 2001/02 Survey. Edinburgh, Scotland: Child and Adolescent Health Research Unit, University of Edinburgh; 2001 (http://www.hbsc.org/overview_studydesign.html).

APPENDIX D

The use of accelerometers for the measurement of physical activity

Overview

In the last decade there has been a major shift from self-report questionnaires to accelerometers as the method used to assess physical activity levels in both laboratory and population based research. Accelerometers provide an objective measure of the duration and intensity of physical activity under free-living conditions.^{1,2} The shift to objectively measured physical activity has advanced physical activity research by eliminating several limitations inherent to self-reported measures that include over reporting the socially desirable behaviours of physical activity, and difficulty assessing intensity of physical activity.^{3,4}

Accelerometers measure normal human movement by assessing vertical acceleration of movement between 0.05 and 2.00 G in magnitude, and frequency of movement between 0.25 and 2.50 Hz.¹ The signal is digitized and converted into a “count” that is averaged over a sampling epoch (e.g., 60 seconds) as a measure of the intensity of activity (i.e. higher counts equals higher intensity of activity) during the epoch over the specified measurement duration (e.g., 7 days). For example, accelerometers can provide a minute by minute objective measurement of the intensity of activity for one week under free-living conditions.

Accelerometers in NHANES

Objective measures of physical activity were included in NHANES starting with the 2003-2004 cycle. Physical activity was measured using Actigraph 7124 activity monitors (Actigraph, Ft. Walton Beach, FL) in participants aged 6 years and older. Participants were provided with activity monitors during the Mobile Examination Center (MEC) exam. The monitors were programmed to start recording at 12:01am on the day

following the exam, and recorded activity for the subsequent seven days. Participants were instructed to wear the monitor during waking hours except when it could get wet. Monitors were attached to custom-fit elasticized fabric belts and worn on the right hip. A one minute sampling epoch was used in the NHANES, therefore, each subject had 10,080 measurements over the seven days of monitoring.

Data from each monitor was downloaded by the Centers for Disease Control and Prevention and checked for spurious data (e.g., biologically implausible values), which were subsequently removed. Monitors were calibrated and the battery life was checked before it was sent out for subsequent use. Due to the large sample size of NHANES, and the amount of data collected for each participant, the physical activity monitor data files downloaded from the NHANES website were extremely large (380MB for 2003-2004, 436MB for 2005-2006).

Data Reduction

Additional spurious data was not removed; however, further data reduction was completed before the physical activity variables that were included in the statistical analyses were created. Data reduction was completed using SAS software version 9.1 (SAS Institute, Carry, NC) and was based on previously published standards.^{1,5}

Initially the data was filtered through an algorithm to removed sections of 20 or more minutes of continuous zero counts indicating non-wear time.⁵ The data was then checked to determine the total wear time for each day. A day was considered complete if there were at least 10 hours of wear time.¹ Finally, subjects were only included if they had at least 4 days of complete monitoring, including at least 1 weekend day. One weekend day needed to be included because physical activity levels in children and youth

have been shown to differ considerably during the week and on weekends.^{1, 6} Four days of monitoring is required for a test-retest reliability of 0.7.¹ In comparison, the test-retest reliability for 1 day of monitoring is considerably lower ranging between 0.31 and 0.49 depending on the age of the youth¹ and was deemed unacceptable.

Measurement of Physical Activity Intensity

For each complete day of monitoring, thresholds of 2000 (equivalent to walking ~4.0 km/h), 3000 (equivalent to walking ~5.6 km/h) and 5200 (equivalent to jogging ~ km/h) counts per minute were used to denote those minutes where the children and adolescent participants were engaged in physical activity of at least a low intensity, moderate-to-vigorous intensity, and vigorous intensity, respectively.⁷ The thresholds used in this study were selected based on available evidence and best judgement of the authors. The minutes of total and moderate-to-vigorous intensity physical activity were averaged across all complete days of monitoring to create the final physical activity variables used for analyses. Total physical activity was calculated as the sum of low, moderate, and vigorous activity. Incidental movement was measured as the mean counts per minute for all minutes below the low intensity physical activity threshold (activity <2000 counts per minute).

Measurement of Bouts of Physical Activity

For each complete day of monitoring, data was filtered to determine the number of minutes spent in sporadic activity (<5 minutes), short bouts (5-9 minute), and medium-to-long bouts (≥ 10 minute) of moderate-to-vigorous intensity physical activity. These bout lengths were selected in part based upon examination of the physical activity data in the study population (e.g., few participants had sessions ≥ 20 minutes) and in part to

represent durations of physical activity that might be suitable for physical activity recommendations. Participants were required to spend at least 80% of the bout above the threshold for the bout to be counted (e.g., for a 5 minute bout, 4 minutes would have to be above 3000 counts per minute). 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). Total physical activity represents the sum of the minutes spent in sporadic, short bouts, and medium-to-long bouts of physical activity. Note that for many participants the average daily minutes spent in bouts fell below the minimum bout duration. This is a reflection of the fact that the average time spent in bouts per day was calculated using the daily average over the week long measurement period and bouts of PA did not occur each day for all participants.

Limitations of Accelerometers

Although objective in nature, accelerometers are not perfect measures of physical activity, and their main limitation is the inability to capture certain types of physical activity.⁸ The vast majority of accelerometers, including those used in the NHANES survey, are not waterproof and cannot be worn during water based activities (e.g., swimming, waterpolo). The accelerometers used in NHANES are uniaxial and only measured the vertical displacement of the body. Therefore, activities involving the upper body (e.g., badminton) or that do not involve vertical displacement of the body (e.g., cycling) would not be accurately captured. Additionally, accelerometers cannot measure the type of activity in which the individual is participating (e.g., running, versus soccer).

References

1. Trost SG, Pate RR, Freedson PS, Sallis JF, Taylor WC. Using objective physical activity measures with youth: how many days of monitoring are needed? *Med Sci Sports Exerc* 2000;32(2):426-31.
2. Van Coevering P, Harnack L, Schmitz K, Fulton JE, Galuska DA, Gao S. Feasibility of using accelerometers to measure physical activity in young adolescents. *Med Sci Sports Exerc* 2005;37(5):867-71.
3. Welk GJ, Corbin CB, Dale D. Measurement issues in the assessment of physical activity in children. *Res Q Exerc Sport* 2000;71(2 Suppl):S59-73.
4. Sirard JR, Pate RR. Physical activity assessment in children and adolescents. *Sports Med* 2001;31(6):439-54.
5. Masse LC, Fuemmeler BF, Anderson CB, et al. Accelerometer data reduction: a comparison of four reduction algorithms on select outcome variables. *Med Sci Sports Exerc* 2005;37(11 Suppl):S544-54.
6. Treuth MS, Catellier DJ, Schmitz KH, et al. Weekend and Weekday Patterns of Physical Activity in Overweight and Normal-weight Adolescent Girls. *Obesity* 2007;15(7):1782-8.
7. Treuth MS, Schmitz K, Catellier DJ, et al. Defining accelerometer thresholds for activity intensities in adolescent girls. *Med Sci Sports Exerc* 2004;36(7):1259-66.
8. Goran MI. Measurement issues related to studies of childhood obesity: assessment of body composition, body fat distribution, physical activity, and food intake. *Pediatrics* 1998;101(3 Pt 2):505-18.

APPENDIX E

Ethics

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

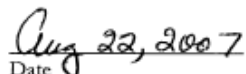
I am writing to acknowledge receipt of your recent ethics submission. We have examined the protocol and consent form for your project (as stated above) and consider it to be ethically acceptable. This approval is valid for one year from the date of the chair's signature below. This approval will be reported 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/vpr/reb.htm>).
- **Reporting of Serious Adverse Events:** Any unexpected serious adverse event occurring locally must be reported within 2 working days or earlier if required by the study sponsor. All other serious adverse events must be reported within 15 days after becoming aware of the information.
- **Reporting of Complaints:** Any complaints made by participants or persons acting on behalf of participants must be reported to the Research Ethics Board within 7 days of becoming aware of the complaint. **Note:** All documents supplied to participants must have the contact information for the Research Ethics Board.
- **Annual Renewal:** Prior to the expiration of your approval (which is one year from the date of the Chair's signature below), you will be reminded to submit your renewal form along with any new changes or amendments you wish to make to your study. If there have been no major changes to your protocol, your approval may be renewed for another year.

Yours sincerely,



Chair, Research Ethics Board


Date

ORIGINAL TO INVESTIGATOR - COPY TO DEPARTMENT HEAD- COPY TO HOSPITAL(S) /P&T (If appropriate) - FILE COPY

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**

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



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
#IRB00001173

Current membership of the Queen's University Health Sciences
& Affiliated Teaching Hospitals Research Ethics Board

Dr. A.F. Clark	Emeritus Professor, Department of Biochemistry, Faculty of Health Sciences, Queen's University (Chair)
Rev. T. Deline	Community Member
Dr. M. Evans	Community Member
Prof. L. Keeping-Burke	Assistant Professor, School of Nursing, Queen's University
Ms. C. Knott	Research & Evaluation, Southeastern Regional Geriatric Program, Providence Care – St. Mary's of the Lake Hospital Site
Ms. S. Marlin	Director, Office of Research Services (Ex Officio)
Dr. J. Low	Emeritus Professor, Department of Obstetrics and Gynaecology, Queen's University and Kingston General Hospital
Dr. W. Racz	Emeritus Professor, Department of Pharmacology & Toxicology, Queen's
Dr. H. Richardson	Assistant Professor, Department of Community Health & Epidemiology Project Coordinator, NCIC CTG, Queen's University
Dr. B. Simchison	Assistant Professor, Department of Anesthesiology, Queen's University
Dr. A.N. Singh	WHO Professor in Psychosomatic Medicine and Psychopharmacology Professor of Psychiatry and Pharmacology Chair and Head, Division of Psychopharmacology, Queen's University Director & Chief of Psychiatry, Academic Unit, Quinte Health Care, Belleville General Hospital
Dr. E. Tsai	Assistant Professor, Department of Paediatrics and Office of Bioethics, Queen's University
Rev. J. Warren	Community Member
Ms. K. Weisbaum	LL.B. and Adjunct Instructor, Department of Family Medicine (Bioethics)

**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


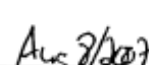
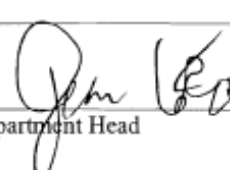
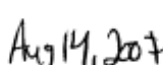
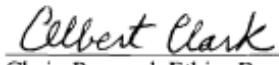
Project Title: Dose-response relation between physical activity and screen time behaviours with health in school-aged youth

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			

APPENDIX F

Sample of Pearson Partial Correlation Output

The SAS System

The CORR Procedure

Pearson Partial Correlation Coefficients, N = 1165 Prob > r under H0: Partial Rho=0				
	slow	smod	svig	avgim
slow	1.00000	0.80254 <.0001	0.48099 <.0001	0.70262 <.0001
smod	0.80254 <.0001	1.00000	0.67331 <.0001	0.44873 <.0001
svig	0.48099 <.0001	0.67331 <.0001	1.00000	0.27515 <.0001
avgim	0.70262 <.0001	0.44873 <.0001	0.27515 <.0001	1.00000

APPENDIX G

Sample of Spearman Rank Correlation Output

The SAS System

The CORR Procedure

Spearman Partial Correlation Coefficients, N = 2396 Prob > r under H0: Partial Rho=0				
	RNKtot	RNKsp	RNKshort	RNKml
RNKtot	1.00000	0.77618 <.0001	0.74872 <.0001	0.74853 <.0001
RNKsp	0.77618 <.0001	1.00000	0.58737 <.0001	0.42764 <.0001
RNKshort	0.74872 <.0001	0.58737 <.0001	1.00000	0.52922 <.0001
RNKml	0.74853 <.0001	0.42764 <.0001	0.52922 <.0001	1.00000

APPENDIX H

Sample of Chi Square Analysis Output

The SAS System

The FREQ Procedure

Frequency Percent Row Pct Col Pct	Table of st by MetSGrp			
	st	MetSGrp		Total
		0	1	
1	421	16	437	
	23.35	0.89	24.24	
	96.34	3.66		
	24.82	14.95		
2	336	16	352	
	18.64	0.89	19.52	
	95.45	4.55		
	19.81	14.95		
3	298	21	319	
	16.53	1.16	17.69	
	93.42	6.58		
	17.57	19.63		
4	236	17	253	
	13.09	0.94	14.03	
	93.28	6.72		
	13.92	15.89		
5	405	37	442	
	22.46	2.05	24.51	
	91.63	8.37		
	23.88	34.58		
Total	1696	107	1803	
	94.07	5.93	100.00	

The SAS System

The FREQ Procedure

Statistics for Table of st by MetSGrp

Statistic	DF	Value	Prob
Chi-Square	4	10.4819	0.0330
Likelihood Ratio Chi-Square	4	10.6678	0.0306
Mantel-Haenszel Chi-Square	1	10.1384	0.0015
Phi Coefficient		0.0762	
Contingency Coefficient		0.0760	
Cramer's V		0.0762	

Sample Size = 1803

APPENDIX I

Sample of Linear Regression Output

Survey linear regression

pweight: weighting
 Strata: strata
 PSU: psu

Number of obs = 1165
 Number of strata = 15
 Number of PSUs = 30
 Population size = 20475248
 F(14, 2) = .
 Prob > F = .
 R-squared = 0.1490

totpctl	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
sex	-11.08721	3.161117	-3.51	0.003	-17.82497	-4.349451
age	-.9976265	.543543	-1.84	0.086	-2.156161	.160908
pirgrpa	-.4648473	3.041846	-0.15	0.881	-6.948389	6.018695
pirgrpb	1.563357	2.043352	0.77	0.456	-2.791945	5.918659
pirgrpc	2.071843	6.537228	0.32	0.756	-11.86193	16.00561
kcal	-.0049455	.0010185	-4.86	0.000	-.0071163	-.0027747
smokegrpa	5.062885	2.622792	1.93	0.073	-.5274632	10.65323
smokegrpb	2.523755	3.034265	0.83	0.419	-3.943628	8.991139
racea	-2.718307	2.397022	-1.13	0.275	-7.827438	2.390824
raceb	3.966922	2.587636	1.53	0.146	-1.548494	9.482338
racec	-11.97901	3.946716	-3.04	0.008	-20.39123	-3.56678
totb	-6.116619	4.28425	-1.43	0.174	-15.24828	3.015043
totc	-2.547705	4.377344	-0.58	0.569	-11.87779	6.782383
totd	-3.921844	6.511529	-0.60	0.556	-17.80084	9.957152
mvb	-6.531712	2.756141	-2.37	0.032	-12.40629	-.6571355
mvc	-11.88919	4.010014	-2.96	0.010	-20.43633	-3.34205
mvdl	-19.1969	6.68026	-2.87	0.012	-33.43554	-4.958263
mvdh	-24.3337	6.75933	-3.60	0.003	-38.74087	-9.926531
vigb	-4.141786	2.898313	-1.43	0.173	-10.31939	2.035822
vige	-5.481711	4.335097	-1.26	0.225	-14.72175	3.75833
vigdl	-5.098112	5.061405	-1.01	0.330	-15.88624	5.690017
vigdh	-3.612033	6.70656	-0.54	0.598	-17.90673	10.68266
imb	4.931763	2.762158	1.79	0.094	-.9556375	10.81916
imc	2.19874	3.217715	0.68	0.505	-4.659658	9.057138
imd	5.581897	2.974801	1.88	0.080	-.758742	11.92254
_cons	88.55418	8.461496	10.47	0.000	70.51892	106.5894

APPENDIX J

Sample of Logistic Regression Output

Survey logistic regression

pweight: weighting
 Strata: strata
 PSU: psu

Number of obs = 2396
 Number of strata = 30
 Number of PSUs = 60
 Population size = 21061521
 F(20, 11) = 3.77
 Prob > F = 0.0139

ovob	Odds Ratio	Std. Err.	t	P> t	[95% Conf. Interval]	
sex	.7180911	.1136902	-2.09	0.045	.5197033	.9922101
age	.9895409	.0402623	-0.26	0.798	.910638	1.07528
racea	1.369619	.2349045	1.83	0.077	.9648921	1.94411
raceb	1.559725	.2509682	2.76	0.010	1.12288	2.16652
racec	.3568969	.1151093	-3.19	0.003	.1847043	.6896177
pirgrpa	1.312128	.1940616	1.84	0.076	.9700591	1.77482
pirgrpb	1.242892	.1914437	1.41	0.168	.907436	1.702357
pirgrpc	.9317858	.4013939	-0.16	0.871	.3865784	2.245922
kcal	.9998067	.0000779	-2.48	0.019	.9996475	.9999658
smokegrpa	1.239943	.1556071	1.71	0.097	.959608	1.602173
smokegrpb	1.159547	.2220293	0.77	0.446	.7842528	1.714433
totalb	.794782	.1174761	-1.55	0.131	.587691	1.074848
totalc	.8190716	.1968456	-0.83	0.413	.5013762	1.338074
totald	.5980693	.2047161	-1.50	0.144	.2972719	1.203231
shortb	1.02615	.157447	0.17	0.868	.7501052	1.403781
shortc	.8080614	.1518288	-1.13	0.266	.5505458	1.186029
shortd	.5244427	.1336554	-2.53	0.017	.3116431	.8825486
medlb	.6984265	.148344	-1.69	0.101	.4526217	1.07772
medlc	.5953662	.1272181	-2.43	0.021	.3848228	.9211017
medld	.5253072	.1466302	-2.31	0.028	.2970556	.9289429