

The Effect of Intermittent Activity on Postprandial Lipemia in Children

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TABLE OF CONTENTS

TABLE OF CONTENTS.....	II
ATTESTATION OF AUTHORSHIP.....	V
CO-AUTHORED WORK	VI
LIST OF TABLES	VII
LIST OF FIGURES	VIII
ACKNOWLEDGMENT.....	IX
LIST OF ABBREVIATIONS AND ACRONYMS.....	X
PUBLICATIONS AND CONFERENCE PRESENTATIONS FROM THIS THESIS	XII
ABSTRACT	XIII
CHAPTER 1: INTRODUCTION	15
BACKGROUND.....	15
Sedentary behavior	15
THESIS RATIONALE	17
Choice of participants	18
Study design and physical activity intensity	18
Outcome measures.....	19
Choice of equipment.....	19
Activity measurement.....	19
Blood withdrawal method.....	20
Selected diet.....	21
Participant behavior	22
Choice of analysis.....	23
ORIGINALITY OF THE THESIS	23
PURPOSE	24
HYPOTHESIS.....	24
THESIS ORGANISATION.....	24
CHAPTER 2: LITERATURE REVIEW	26
ABSTRACT.....	26
INTRODUCTION	27
METHODS.....	28

Literature search	28
Inclusion criteria	28
Selection process	28
RESULTS	29
Subjectively measured sedentary time.....	43
Objectively measured sedentary time	44
Subjectively and objectively measured weekday and weekend time	44
DISCUSSION	48
Measurement of sedentary behavior	48
Health outcomes	50
Interrupting sedentary activities.....	51
Limitations.....	52
CONCLUSION.....	52
 CHAPTER 3: EFFECT OF INTERMITTENT SITTING ON ACUTE POSTPRANDIAL LIPEMIA IN CHILDREN: A FEASIBILITY STUDY	 54
ABSTRACT.....	54
INTRODUCTION	55
METHODS.....	56
Participants	56
Preliminary measures.....	56
Experimental design and procedures	57
Dietary intake	59
Blood analysis.....	60
Statistical analysis.....	60
RESULTS	61
DISCUSSION	68
 CHAPTER 4: DISCUSSION.....	 71
CONTEXT	71
Measurement of sedentary behavior	71
SIGNIFICANCE OF THE FINDINGS	72
Lifestyle disease in pre-adolescent children	72
Intermittent activity and postprandial clearance	73
Physiological interpretation	73
Statistical interpretation	75
FEASIBILITY AND IMPROVEMENT OF THE METHODS	76
Participants	76
Methodology.....	76
STRENGTHS AND LIMITATIONS.....	81
FUTURE DIRECTIONS	83
Future sedentary behavior and health research	83

CONCLUSIONS	84
REFERENCES.....	85
APPENDICES	105
APPENDIX A: PARTICIPANT COMPLIANCE LOG.....	106
APPENDIX B: PARTICIPANT FOOD QUESTIONNAIRE	108
APPENDIX C: PARTICIPANT DAILY DIET	111
APPENDIX D: LETTER OF RECOMMENDATION TO PARENTS.....	113
APPENDIX E: DATA COLLECTION SHEET.....	116
APPENDIX F: PARTICIPANT INFORMATION SHEET	118
APPENDIX G: PARENT/GUARDIAN INFORMATION SHEET	124
APPENDIX H: PARTICIPANT ASSENT FORM	132
APPENDIX I: PARENT/GUARDIAN CONSENT SHEET	134
APPENDIX J: APPROVAL LETTER FROM ETHICS COMMITTEE	137
APPENDIX K: COHEN’S D EQUATION	140
APPENDIX L: RELIABILITY OF THE ACTIVPAL INCLINOMETER IN DETERMINING SITTING, STANDING AND STEPPING TIME IN NEW ZEALAND CHILDREN.	142

ATTESTATION OF AUTHORSHIP

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of a University or other institution of higher learning, except where due acknowledgement is made.

Name Here -----

Date -----

This thesis has been presented in American English.

CO-AUTHORED WORK

Chapters 2 and 3 of this thesis, and Appendix L, represent three separate papers that will be submitted to peer-reviewed journals for consideration for publication. All co-authors have approved the inclusion of the joint work in this Master's thesis.

Paper 1

Title: Sitting time and associations with health outcomes in pre-adolescents: A review of the evidence.

Chapter in thesis: Two

Percentage contribution: 80% of work is my own, 15% is that of Dr Erica Hinckson and 5% is that of Caryn Zinn.

Paper 2

Title: Effect of intermittent sitting time on acute postprandial lipemia in children.

Chapter in thesis: Three

Percentage contribution: 77.5% of work is my own, 20% is that of Dr Erica Hinckson, 2.5% is that of Caryn Zinn.

Paper 3

Title: Reliability of the ActivPAL inclinometer in determining sitting, standing and stepping time in New Zealand children.

Appendix L

Percentage contribution: 10% of work is my own, 60% is that of Dr Erica Hinckson, 20% is that of Professor William Hopkins, 10% is that of Saeideh Aminian.

LIST OF TABLES

Table 2.1. Articles that reviewed sedentary behavior in children and/or adolescents.

Table 2.2. Subjective and objective studies that measure time spent in sedentary activity in pre-adolescent (8-15y).

Table 3.1. Descriptive participant characteristics (mean \pm SD) (n=12).

Table 3.2. Overall means and SD and % difference in the mean between day 1.

Table 3.3. Overall TAG results for day 1 and day 2 for all tests.

Table 3.4. TAG results for day 1 and day 2 in eight participants.

Table A.1. Descriptive characteristics (mean \pm SD) for the elementary school children in Auckland New Zealand (2009-2010).

Table A.2. Daily sitting, standing, stepping, step counts and sit-to-stand counts during periods of weekday and weekend days for girls (G) and boys (B) in Auckland, New Zealand (2009-2010). Data are mean \pm SD.

Table A.3. Daily sitting, standing, stepping, step counts and sit-to-stand counts over 24 hour for weekday and weekend days for girls (G) and boys (B) in Auckland, New Zealand. Data are mean \pm SD, girl-boy comparison with $\pm 90\%$ confidence limits (CL), typical error, and intraclass correlation coefficient (ICC).

LIST OF FIGURES

Figure 1.1 The sequence of the study and specific aims.

Figure 2.1. Process of exclusion and selection for subjective and objective measurements of sedentary activity.

Figure 3.1. Schematic representation of the testing period on day 1 and day 2.

Figure 3.2. Overall TAG results for day 1 and day 2, raw data including T5.

Figure 3.3. TAG results for day 1 and day 2 in eight participants, raw data excluding T5.

Figure 3.4. TAG results for day 1 and day 2 in four participants, raw data excluding T5.

Figure 4.1. Child development periods.

Figure A.1. Cohen's d effect size equation

Figure A.2. The ActivPAL monitor, silicon pocket and water-resistant Velcro belt. The ActivPAL monitor unit is placed on anterior mid-thigh section.

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I wish to acknowledge the support of my family who have never lost interest in my research. Lastly, to John, it's hard for me to describe in words my appreciation for your devotion, love and moral guidance. Thank-you from the bottom of my heart.

LIST OF ABBREVIATIONS AND ACRONYMS

BMI:	body mass index
TAG:	triacylglycerol
PPL:	post prandial lipemia
NEAT:	non exercise activity thermogenesis
HDL:	high density lipo-protein
LDL:	low density lipo-protein
LPL:	lipo-protein lipase
SD:	standard deviation
CL:	confidence limits
ICC:	intraclass correlation coefficient
METS:	metabolic equivalent for task

This thesis has received approval from the following ethics committees: Auckland University of Technology (15/9/2010:10/179)

PUBLICATIONS AND CONFERENCE PRESENTATIONS FROM THIS THESIS

Peer-reviewed Journal Publications

Chapters 2 and 3 of this thesis represent individual papers that will be submitted to peer-reviewed journals for consideration for publication. These papers are listed below.

Faithfull, K., Hinckson, E. H., & Zinn, C. (2011). Sitting time and associations with health outcomes in pre adolescent youth: A review of the evidence. *Journal of Physical Activity and Health, under review.*

Faithfull, K., Hinckson, E. H. (2011). Effect of intermittent sitting time on acute postprandial lipemia in children: a feasibility study. *Journal of Physical Activity and Health, under review.*

Conference Presentations and Associated Publications

Faithfull, K. (2010, November). *Effect of intermittent sitting time on postprandial lipemia in children.* Paper presented at the AUT Maori and Pasifika Symposium, Auckland, New Zealand.

Faithfull, K., Hinckson, E. H. (2011, June). *Intermittent effect of sitting time on postprandial lipemia in children.* Paper presented at the Satellite Meeting of the International Society for Behavioral Nutrition and Physical Activity Beyond 2011: New Paradigms to Improve Physical Activity & Nutrition, Queenstown, New Zealand.

Faithfull, K., Hinckson, E. H. (2011, October). Effect of interrupting sitting time on acute postprandial lipemia in healthy children. *Invited to present.* Australian Conference of Science and Medicine in Sport, October 2011, Perth, Australia.

ABSTRACT

Time spent in sedentary behavior has been linked to negative health outcomes such as obesity and dislipidemia in children and adolescents. Interrupting sitting time has been shown to improve metabolic health in adults; however no studies have been conducted with pre-adolescent children. Pre-adolescence is the time of steepest decline in physical activity, so this is a high-risk age group. Nevertheless, time spent in sedentary activities over the course of the day varies and this may be due to differences in the measurement of sitting time. Therefore, the first aim of this research was to critically review the objective and subjective measures of time spent in sedentary behavior in pre-adolescent children and to report the associations between time spent in sedentary activity and health outcomes. Understanding current levels of sedentary behavior and associated outcomes may reinforce policy to support interventions aimed at decreasing or interrupting time spent sitting. The review illustrated that pre-adolescent children spend a substantial proportion of time in sedentary behavior (3 – 8 hours per day) and that the measurement of sedentary behavior is complex, with time spent being sedentary being both over- and underestimated.

The second aim of this thesis was to investigate whether interrupted sitting with physical activity increased fat (postprandial) clearance in pre-adolescents after a high fat meal. Previous studies have suggested that intermittent activity may decrease lifestyle disease risk factors. Twelve children underwent two 8.5-hour testing sessions separated by seven days. On day 1 participants interrupted sitting with moderate intensity physical activity every 30 minutes, on day 2 participants remained sedentary. Four meals high in fat were consumed to ensure blood lipids were raised after consumption. Meals selected simulated, with exaggeration, unhealthy eating patterns in children. Blood tests were taken every second hour from 8.30am to 4.00pm to measure triacylglycerol (TAG), glucose, and cholesterol levels. When sedentary activity was interrupted by short bouts of moderate intensity physical activity there was a clear reduction in TAG concentrations in eight out of 12 participants. The combined responses showed higher levels of TAG on day 1 (intermittent sitting) than day 2 (continuous sitting). The difference was -3.2%; (90% confidence limits ± 36.5), but the clinical significance of the effect was unclear.

The third aim of this thesis was to discuss the feasibility of methods in measuring postprandial lipemia in children. The protocol in interrupting sitting time with moderate-high intensity activities and frequent blood sampling was deemed feasible with this group of children. However, future studies with larger sample size are necessary to confirm results.

CHAPTER 1: INTRODUCTION

BACKGROUND

Sedentary behavior

Sedentary behavior has been identified as a risk factor for lifestyle disease (1-4) independent of whether individuals meet daily physical activity guidelines (5). Sedentary behavior can be defined as the amount of time an individual spends in low energy activities during the course of a day or any behavior associated with prolonged sitting (6-9). Examples of sedentary activities in children include completing homework, motorised passive transport, sitting and talking and screen based medias (playing computer/video games and watching television) (10). Traditionally, sedentary behavior in children has been quantified in hours spent watching TV or screen-time (11, 12). Findings indicate that on average children spend 2-3 hours per day watching television and more than 4 hours per day in screen based media (10, 13). More recently, objective studies using accelerometers have offered a 24-hour representation of time a child may spend in sedentary activity (14-16).

Lifestyle disease risk factors, including diabetes and obesity have been noted in adults (17-19) and identified in children under the age of ten (20). Lifestyle disease risk factors play a role in the development of cardiovascular disease. Although physical inactivity is also a prominent risk factor of lifestyle disease, relatively little is known about how sedentary behavior may influence lifestyle disease trends in children (21). In order to understand how sedentary behavior may lead to negative health outcomes, Hamilton et al (22) suggested that it is important to study sedentary behavior separately from physical activity or physical inactivity (23-25). Research has shown that sitting for comparatively long periods of time can cause the loss of thousands of small muscular contractions over the course of a day resulting in the loss of opportunity for cumulative energy expenditure or non-physical activity activity thermogenesis (NEAT) (26). An individual can spend up to one-half of their day sitting with relatively idle muscles (27, 28).

One way to explore the consequences of sedentary behavior is to examine postprandial lipemic response. Postprandial lipemia is the inability to rapidly clear intestinally-derived particles (chylomicrons) following high lipid dietary intake (29), playing an important role in the development of cardiovascular diseases. It is speculated that high

levels of fatty acids are produced by the malfunctioning of lipoprotein lipase (LPL) activity after the consumption of a high fat meal. LPL is an enzyme that functions primarily on the surface of endothelial cells, regulating plasma triacylglycerol (TAG) and high density lipoprotein (HDL) cholesterol (21, 29-31). Therefore, postprandial lipemia is considered an important feature of obesity, insulin resistance, and cardiovascular disease in adults (32). During the fasted state, chylomicrons (particles transporting dietary fat in the blood circulation) are produced and secreted by the intestine at a basal rate, and the ingestion of a fat-containing meal leads to an increased secretion. Normally, chylomicrons are broken down within the circulation by LPL (33).

Although the link between sedentary behavior and postprandial lipemia is a relatively unexplored field of research in children, there is not enough evidence to review findings. LPL however, has been extensively studied as an enzyme that has a central role in several aspects of lipid metabolism in adults and adolescents (29, 34-36). LPL activity appears to be reduced in response to both acute and chronic sedentary behavior (37), and in obese individuals (38). Bey et al (39) first examined the regulation of LPL activity in skeletal muscle during periods of prolonged sedentary behavior in comparison to low-intensity contractile activity in mammals. They concluded that LPL activity is profoundly suppressed by inactivity in skeletal muscles compared with low-intensity ambulatory activity. Similar findings in healthy adults showed suppressed activity after long bouts of bed rest (40, 41) suggesting that low levels of the LPL enzyme are associated with increased circulating TAG levels, decreased HDL cholesterol, and an increased risk of cardiovascular disease (22).

The effects of intermittent physical activity in **adult** populations have also yielded insights into postprandial responses. Studies have shown comparisons of postprandial response to intermittent activity and continuous physical activity (42-46). Study protocols included participants consuming at least one high fat test meal and in two cases each intermittent activity bout was directly followed with a test meal (42, 43). Intermittent activity included three walks for 10mins (42), three walks for 30mins (43), 5 walks for 5 mins (47) or 10 walks for 3mins (44, 45, 48). It was first noted by Alena et al (46) that studies in which participants consumed continuous high fat meals over the course of the day, may be difficult to interpret. In these studies, test meals were regularly consumed or postprandial lipemia was measured after each short bout of intermittent physical activity. Although results may have been unclear due to

intermittent accumulation, or from testing directly after intermittent bouts, all investigators have established similar findings (42-45). Findings suggested that both continuous physical activity and intermittent activity significantly reduced postprandial lipemia, but postprandial lipemia response was not different between activity types (42-45). In contrast, one investigator had noted a lower postprandial response during intermittent activity than continuous physical activity (46).

Studies in **adolescents** have used the postprandial lipemic response to measure the effect of acute and intermittent physical activity prior to, and after, a high fat meal (36, 49-53). Earlier studies however, had been largely limited to observational assessment of the influence of fat distribution and growth hormone deficiency (53, 54). In 2007, Barrett et al (52) investigated the effect of physical activity on postprandial lipemia in adolescents and reported a ~20% reduction in postprandial TAG after continuous and intermittent moderate activity (51, 52). The study provided the first insight into the positive health effects of intermittent activity. More recently, MacEneaney et al (36) examined the effect of physical activity in normal weight and overweight adolescents prior to a high fat meal. They noted that physical activity before ingestion of a high fat meal reduced postprandial lipemic response.

The only study in **children** was undertaken by Bueno et al (55) who examined the relationship between postprandial lipemia and body fat composition in 13 obese girls aged 8-14 years. Blood samples to determine a full lipid profile were taken at baseline and a high fat meal was consumed thereafter. Further lipid profiling was completed 2hr, 4hr, and 6hr after baseline. No further methodological information was provided in this paper and therefore it was difficult to compare protocols. The study found significant correlations between waist to hip ratio and peak TAG value, but did not provide any correlations between postprandial lipemia, LPL mechanisms and sedentary behavior. These findings in adolescents and adults suggest that intermittent activity could increase postprandial clearance in children.

THESIS RATIONALE

Time spent in sedentary behavior may lead to a number of negative health outcomes in pre-adolescent children. Poor agreement exists between studies on the total amount preadolescents spent in sedentary pursuits due to perhaps the use of different tools to quantify sedentary behaviour. In addition, evidence suggests that there are a number of

positive associations to interrupting sitting time in adults and adolescents. Hence this thesis aims to report the time pre-adolescents spent in sedentary behavior and the effects of interrupting sitting time in pre-adolescent children.

The section below describes the choice of participants, the study design, outcome measures used, choice of equipment, the blood withdrawal method, the selected diet, participant behavior, and choice of analysis. This is followed by a descriptive statement to the originality of the thesis, the purpose, hypothesis and thesis organisation.

Choice of participants

Pre-adolescent primary school children from mixed backgrounds aged between 8-13 years were included in this research. Emerging research suggests that pre-adolescents in New Zealand between the ages of 7-12 years are exposed to more opportunities to engage in sedentary activities and will utilize labor-saving devices more frequently than adults (56). Research measuring time spent in sedentary behavior has indicated that pre-adolescents engage in higher levels of sedentary activity than adolescents or young children (57). Despite this evidence, overweight and obesity in youth is also increasing (58, 59). Participants included four male and eight female children with mixed ethnicities, representing from both high and low socio-economic areas in Auckland, New Zealand. Cole cut points (60) are used to define the proportion of participants who are healthy or overweight.

Study design and physical activity intensity

A repeated measures within-subject design was employed in this study. Independent variables included age, bodyweight and sitting time. The dependent variables were blood parameters; glucose, cholesterol and TAG. Participants were required to attend two testing days, seven days apart. On day 1 participants engaged in a 4-minute intermittent activity bout every 30 minutes. The activity was designed to be of moderate to vigorous intensity, comparable to research with similar designs. Previous protocols utilized intermittent activity time that consisted of three walks for 10 mins (42) or three walks for 30 mins (43) or 5 walks for 5 mins (47) or 10 walks for 3 mins (44, 45, 48) over the course of a testing period. Recent research has since suggested that an intermittent activity bout of 3 minutes every 30 minutes is required to reduce TAG levels prior to a high fat meal consumption (45). Three to four minutes of intermittent activity is comparable to activity behavior patterns in pre-adolescent children, who will

regularly undertake numerous short bouts of moderate to intense physical activity throughout the day (61).

Outcome measures

In this study plasma TAG were used to measure postprandial response to LPL activity. High levels of TAG are associated with Metabolic Syndrome (METS) (29) in children and are associated with risk factors such as dyslipidemia, atherosclerosis, obesity, type 2 diabetes and cardiovascular disease (31, 62). As it has been discussed earlier, previous studies examining the effect of complete (11 and 5 days respectively) bed rest (rising only for matters of personal hygiene) on metabolic health found that, TAG, glucose, total cholesterol, and insulin resistance increased significantly (40, 63). These results suggest that an extended dose of sedentary behavior can result in dramatically increased metabolic risk.

Choice of equipment

Activity measurement

Quantitative measurement

The ActivPAL™ accelerometer was selected to record step count and cadence of activity level in all participants. The ActivPAL™ accelerometer is a single unit device, requiring no calibration and attaches to the anterior thigh. The accelerometer uses piezoelectric technology to detect acceleration and change in posture. The reliability of the ActivPAL™ accelerometer has been compared to similar step measuring devices: The Yamax® Digi Walker SW401, PALlite (64), Omron HJ-109-E, Yamax® Digi-Walker SW200 (65) and Step watch™ (66) in healthy adults. The results highlighted the ActivPAL™ has a 99.9% reliability (ICC 0.99) and an absolute value of percentage error of 1.2%. Although no studies have yet been published in child populations, unpublished work by Aminian and colleagues (67), established that the ActivPAL™ accelerometer is a valid device with a strong validity correlation ($r=0.88-1.00$) during walking in children. The accelerometer was chosen over similar objective measurement tools, such as the pedometer, due to its functionality and ability to objectively measure time spent in sedentary activity.

Qualitative self reporting measurement

During activity measurement participants were asked to self report any times the ActivPAL™ accelerometer was removed onto daily activity logs (Appendix A). Participants also recorded bed time (lights out) and awakening time, which used to compare with activity records from the ActivPAL™. Activity logs are frequently used to measure adherence to physical activity recommendations in large populations (68-70).

Blood withdrawal method

There are a variety of techniques and tools to achieve blood withdrawal. Finger pricking is a commonly used method of blood withdrawal in paediatric populations and is carried out using a lancet. In this study high flow paediatric lancets were used. A lancet is a small sharp spring loaded metal fragment used to create a superficial wound. Wound incisions can be of different sizes and depths depending on the type of lancet used. Finger pricking is simple to perform and cheaper than alternative methods (71). Paediatric lancets are also used for children to encourage consistent and longer bleed time, however there is no evidence or research to support increased blood flow. The advantage of paediatric lancets is that needles retract immediately after pricking to avoid accidental re-pricking. As participants are considered vulnerable, we opted to remove no more than the necessary amount of blood and deemed it unsuitable to leave a needle in the participant's arm during moderate intensity physical activity.

Another routinely performed procedure to withdraw blood is venepuncture. Venepuncture is considered the most effective method to withdraw large samples of blood. A needle is inserted directly into a vein and blood is quickly drained into a waiting test tube. Venepuncture is used to collect larger samples of blood required for a number of different tests. A closed tube can be left in the vein for continuous blood withdrawal. Common risks of venepuncture include clotting, air embolism, infection, venous spasm and phlebitis. The insertion of the needle penetrates the skin defence mechanism and may result in exposed risks and problems for a patient if not performed correctly (72). Research suggests that ratings of perceived pain and distress are higher in children who experience venepuncture than finger pricking (73). Both withdrawal methods have small risks involved including infection, bruising and acute pain, but are more significant in venepuncture. Researchers involved in postprandial studies in adults

and adolescents have opted for venepuncture; however due to the age, activity requirements of the participants and amount of blood required in this study it was deemed more suitable to use finger pricking.

Selected diet

In this study participants consumed one baseline meal and three smaller meals, all high in fat, over the course of 7 hours. The diet was designed to be high in fat to cause a marked postprandial lipemic response, and cause an increase in chylomicron secretion. In order to increase TAG concentration and monitor a postprandial response, it is recommended that test meals contain at least 30% of the energy derived from fat (74). Consecutive high fat meals of 40 - 50g are shown to further enhance lipemia (75) as simulated previous research has shown (42, 43).

The baseline meal consisted of a McDonald's double quarter pounder with cheese, medium fries and a hash-brown, and a home-made Milo beverage made with full-fat milk. Similar studies in adolescents have offered high fat food choices including croissants, chocolate, ice cream and potato chips (36) or ice cream based milkshakes and foods (49, 51, 55). The amount of fat per kilogram of body weight in the previous adolescent studies has ranged from 1.5g (51) to 1.3g (52) or 97g per 2m² body surface area (36) or 52.5g per m² (49). In this study the combined meals consisted of approximately 1.9g fat, 3.1g carbohydrate and 1.6g protein per kilogram of body weight. The ratio energy percentage equaled 46% fat, 36% carbohydrate and 18% protein.

Prior to diet formulation participants completed a questionnaire on their food and drink preferences (Appendix B). All participants identified they wanted to eat a McDonald's burger. McDonald's is the leading world-wide hamburger and food service retailer and there is evidence suggesting that children as young as three prefer the taste of food when they believe that food is from McDonald's (76). Based on these insights we decided to provide a fast food option that was familiar and which children were likely to consume. The New Zealand Health Survey 2006/07 showed that in New Zealand 70.9% of children eat fast food at least once a week (77). Unhealthy fast foods are associated with an increased risk of weight gain and are generally high in fat, salt and sugar (78). The remaining three smaller meals were designed to replicate a child's typical eating times (79) during the day (morning tea, lunch and afternoon tea) and provide a diet that

included substantial amounts of fat, sugar and salt. The meals included the following: one cheese and bacon croissant, 200g chocolate or goody gum drops ice-cream, one cream doughnut and two full-fat milk-based drinks. For a complete list of the day's food and fluid items refer to Appendix C. Participants were encouraged to consume as much as they were able and stopped eating when full. The remaining food was weighed to determine remaining macro-nutrient composition. Parents were provided information (Appendix D) with suggestions on preparing a meal of fruit and vegetables if their child was hungry later in the evening. Suggestions were based on the New Zealand Food and Nutrition guidelines (80).

Participant behavior

Intermittent Physical activity

In this study all participants were encouraged to participate at a moderate level of activity when completing intermittent activity bouts. Physical activity intensity was measured by ActivPAL accelerometer which was worn for the entire testing period. Moderate intensity activities included soccer, basketball, obstacle courses, stair climbing, dancing, aerobics, frisbee, cart wheel races and touch rugby. Activities were selected in consultation with local school holiday programme co-ordinators and were designed to stimulate and challenge participants aged between 8-14 years as well as being enjoyable (81, 82).

Intermittent activity bouts (as distinct from the overall volume of time spent being sedentary) have been shown to have beneficial associations with metabolic biomarkers and lower postprandial TAG (42, 43, 83, 84). Healy et al (83, 85) first noted that there was a positive association between breaks in sedentary time and waist circumference, body mass index, TAG and 2h glucose in adults after 7 days of objective measurement, providing confirmation of the likely metabolic health benefits of regular interruptions to sitting time (86). In response, several research-based recommendations state that health can be improved through physical activity bouts accumulating to at least 30 min of moderate intensity lifestyle activities on most, if not all, days of the week (87-90). In addition, further research has since emphasised the negative consequences of continuous sedentary engagement (84, 91).

Sedentary Behaviors

The sedentary activities in this study were chosen by participants prior to testing. To enhance engagement, on enrolment, each participant was asked which sedentary activities they enjoyed participating in regularly. Selected activities were recorded on participant information sheets. The most common sedentary activities in order of preference were: TV watching, PlayStation[®], computer games and reading.

Choice of analysis

Comparisons were drawn between all measures: TAG, cholesterol and glucose using area under the concentration-time curve. Area under the concentration-time curve is used to standardise the effect of change over time. The calculated mean area under the concentration-time curve between each measure on day 1, were compared to the mean area under the concentration-time curve of day 2 using paired t-tests. Further explanation of the data analysis is found in Chapter three. Paired t-test was used to determine the significance of the difference between day 1 and day 2. The paired t-test is most commonly applied when a test statistic would follow a normal distribution and can be used to compare findings. For instance, the comparison of day 1 and day 2 in each participant. Hopkins spreadsheets (92) were then used to provide estimates of magnitude based inferences. The smallest standardized change was assumed to be 0.2 (93). The value of 0.2 ensures that the true effect is at least small. To make inferences about true (population) values on the effect, the uncertainty in the effect was expressed as 90% confidence limits and as likelihoods that the true value of the effect represents substantial change (negative or positive) (92). Hopkins spreadsheets are used to provide clarity and accuracy in data analysis and will accurately provide reliability, validity, assessment of an individual, confidence limits and clinical significance from a data set.

ORIGINALITY OF THE THESIS

This research provides the first insight into quantifying the effect of intermittent activity on postprandial lipemia in sedentary children, using metabolic parameters. Research has accentuated the importance of providing further evidence of the metabolic effects of sedentary behavior in adults and children (23, 29, 37, 62, 86) to gain further understanding of how prolonged sitting leads to negative health effects. The uniqueness of this thesis is further enhanced with its replication of usual child activity patterns and includes commonly consumed dietary foods of New Zealand children.

PURPOSE

The primary purpose of this thesis was to investigate and quantify the measurement of sedentary behavior in pre-adolescents and examine the effect of intermittent activity on postprandial lipemia in children. The specific aims of this research were as follows:

1. To critically review the objective and subjective measures of time spent in sedentary behavior in pre-adolescent children and to report the associations between time spent in sedentary activity and health outcomes.
2. To investigate whether intermittent activity increases postprandial clearance.
3. To discuss the feasibility of methods in measuring postprandial lipemia in children.

HYPOTHESIS

With respect to the primary purpose it was expected that:

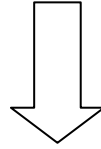
Intermittent activity completed every 30 minutes on day 1 will reduce the level of postprandial lipemic response in children compared to day 2 where children remain sitting.

THESIS ORGANISATION

This thesis consists of four chapters. Chapter 2 is the literature review, and focuses on the measured time spent in sedentary behaviors in children. Chapter 3 details the study and describes the research methodology and findings. Chapter 4 provides a conclusion to the thesis with further discussion of findings. The sequence of chapters and their specific aims are depicted in Figure 1.1.

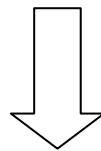
Chapter One: Introduction

Background, rationale, measures, design and organisation.



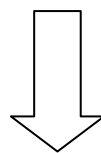
Chapter Two: Literature Review

A systematic literature review of published studies that objectively and subjectively measure sedentary activities in pre-adolescent (8-15 years) and the associations with negative health outcomes.



Chapter Three: Methodology/ Results /Findings

An investigation of the effect of interrupting sitting on acute postprandial plasma triacylglycerol (TAG) in healthy children.



Chapter Four: General Discussion

Thesis results, discussion and implications for future research.

Figure 1.1. The sequence of the study and specific aims

CHAPTER 2: LITERATURE REVIEW

This chapter comprises the following paper will be submitted to the Journal of Physical Activity and Health. “Sitting time and associations with health outcomes in pre-adolescents: A review of the evidence”.

Sitting time and associations with health outcomes in pre-adolescents: A review of the evidence

ABSTRACT

Purpose: Time spent in sedentary behavior may be linked to several negative health outcomes, however studies utilize different measures to report time spent in sedentary behavior. The aims of this paper are to critically review published studies which measure sedentary activities in pre-adolescents, to quantify time spent sitting and identify associations with negative health outcomes.

Methods: Ovid, SportDiscus, Web of Science, Proquest and Google Scholar were used to search for articles from 1990 to the present detailing objectively and subjectively measured SB. Review articles were also scrutinised for further studies.

Results: 82 subjective and 30 objective studies on sedentary behavior measurement were identified. Time spent in sedentary behavior varied for objective measurement (3 - 7 hrs) and subjective measurement (3 - 8 hrs). But overall results were agreeable. Pre-adolescents spending more than 3hrs per day with screen based media were at high risk of being overweight, having obesity and developing cardiovascular disease risk factors.

Conclusion: Pre-adolescents spend a substantial proportion of time in sedentary behavior. Measurement of sedentary behavior is complex and consequently time spent being sedentary is both over and underestimated. Prolonged periods of sedentary behavior should be discouraged and future interventions should aim to decrease or interrupt time spent being sedentary.

Key words: Sedentary behavior, review measurement, screen-time

INTRODUCTION

Given the ubiquitous nature of sitting in modern society, it is hardly surprising that sedentary activities are considered popular by pre-adolescents (94, 95). Sedentary behavior, the amount of time an individual spends in low energy activities during the course of a day (96-98), has been linked to several negative physiological and psychological health outcomes in pre-adolescents (99).

Subjective methods for measurement of physical activity and sedentary behavior (self-reporting questionnaires, activity diaries, habit books and momentary assessments) (100) provide useful evidence on the context of sedentary activities. Self-report instruments have been the most widely used method for measuring sedentary behavior (101) and are favoured for reaching large scale groups at a low cost (102). Although subjective measurement has limited comparability with objective measures due to lower validity, differing recall periods and poor recall in pre-adolescents (101-105), it still remains a popular method to assess activity patterns in this age group.

Objective methods for measurement of sedentary behavior (accelerometers, inclinometers and event loggers) (16, 106-109) can quantify total time spent in sedentary activity (110) and have been validated on children (111). Tools for the objective measurement of sedentary behaviors have the ability to continuously record activity data (i.e. sedentary to vigorous) and specific movement (i.e. sitting to standing) over user-specified time. Although accelerometry has some limitations, such as poor compliance, it provides significant advantages for measurement of sedentary behavior (106, 112, 113). Measuring time spent in sedentary behavior is unlikely to be accurately represented by one activity (110, 114), but rather a number of sedentary activities throughout the day. Despite the accuracy of objective measures, they do not give researchers an understanding of the type of activities pre-adolescents engage in without comparable subjective tools.

Young people have a number of opportunities to engage in sedentary activities over the course of a day, but due to differences in measurement methods, studies may present over- or underestimations of time spent in sedentary behavior. In this paper, we will examine and discuss the following questions below, and make future recommendations.

1. How do subjective and objective measures of sedentary behavior differ in quantification of time spent being sedentary in pre-adolescents?
2. What are the associations between sedentary behavior and adiposity, food consumption and other health outcomes?

METHODS

Literature search

A search of Ovid, SportDiscus, Web of Science, Proquest and Google Scholar was used to obtain articles that measured sedentary behavior objectively or subjectively through self-reporting. Key search terms used were: “sedentary behavior” or “sitting”, or “physical activity”, or “measuring”, or “accelerometer”, or “screen-time” or “child” or “pre-teen” or “adolescent” “or “pre-adolescents”. An author search was conducted for research published by prominent authors (Epstein, Biddle, Reilly, Martinez-Gomez and Rowlands) in the field of sedentary behavior. Prominence was defined by the number of studies the researcher has conducted in the area of childhood sedentary behavior. Review articles and references were scrutinised to locate additional papers.

Inclusion criteria

Studies were included if they met the following criteria (i) Published full-text articles in English language; (ii) published from 1990 to the present (iii) participants were between the ages of 8-15 years; (iv) reported objectively or subjectively measured time in sedentary behavior.

Selection process

Titles and abstracts of citations identified through the search process were reviewed to select relevant articles. Each article was independently reviewed by the primary investigator and a senior academic for eligibility. Any differences were noted and resolved by discussion. Review articles that were examined as part of the selection process are presented in Table 2.1.

RESULTS

Table 2.1. Articles that reviewed sedentary behavior in children and/or adolescents

Sedentary Behavior Reviews

Reference	Sample Size	Objective of Review
Biddle et al (115)	Not stated	To determine interrelationships between physical activity and health in young people using the behavioral epidemiology framework.
Rey-Lopez et al (116)	71	To determine the effect of adiposity of differing sedentary behaviors.
Biddle et al (117)	14	To analyze the tracking of sedentary behavior from childhood or adolescence.
Tremblay et al (37)	Not stated	To advance and extend the discussion first forwarded by Hamilton et al. (2004).
Salmon et al (118)	Not stated	To review the effectiveness of intervention strategies to reduce children's sedentary behavior.
Marshall et al (119)	90	To: (i) estimate the prevalence and dose of television (TV) viewing, video game playing and computer use, and (ii) assess age-related and secular trends in TV viewing among pre-adolescents.
Marshall et al (23)	Not stated	To present (1) a systematic research framework to guide the spectrum of descriptive, analytic, and intervention studies related to sedentary behavior; (2) a summary of the evidence from each phase of the systematic framework applied to sedentary behavior; and (3) implications and recommendations for future research.
Lubans et al (120)	26	To evaluate the reliability and validity of methods used to assess the multiple components of sedentary behavior in children and adolescents (i.e. screen-time, sitting, not moving and existing at low energy expenditure) by systematically reviewing the existing literature.

Physical Activity and Sedentary Behavior Reviews

Reference	Sample Size	Objective of Review
Cliff et al (121)	20	To review the increase in at least one physical activity outcome at post test or follow up.
Kohl et al (122)	50	To review and synthesise available evidence on reliability and validity of physical activity assessment techniques.
Must et al (96)	20	To review the relationship between physical activity and sedentary behavior with overweight & adiposity- emphasis on methodological issues.
Sallis et al (123)	108	To review and assess variables associated with children's and adolescents' physical activity.
Sirad et al (124)	59	To review the strengths, limitations and validity of the subjective and objective techniques that have been developed to assess physical activity in children and adolescents.
Strong et al (125)	850	To review the effects of physical activity on health and behavior outcomes and develop evidence-based recommendations for physical activity in pre-adolescents.

Accelerometer Reviews

Reference	Sample Size	Objective of Review
de Vries et al (126)	32	To review the reproductivity, validity and feasibility of motion sensors used to assess physical activity in children and adolescences.
de Vries et al (107)	35	To review the clinimetric quality of motion sensors used to assess physical activity.
Freedson et al (112)	35	To review the calibration of four different accelerometers used most frequently to assess physical activity and sedentary behavior in children.
Trost et al (127)	Not stated	To investigate methodological issues relating to conducting accelerometer-based assessments of physical activity.
Rowlands et al (106)	Not stated	To provide a contemporary overview of accelerometry research in children.
Rielly et al (110)	Not stated	To review objective measurement of physical activity and sedentary behavior.

Eligible articles included 82 studies that subjectively measured sedentary behavior and 30 studies that objectively measured sedentary behavior. Figure 2.1 below illustrates a summary of the exclusion process.

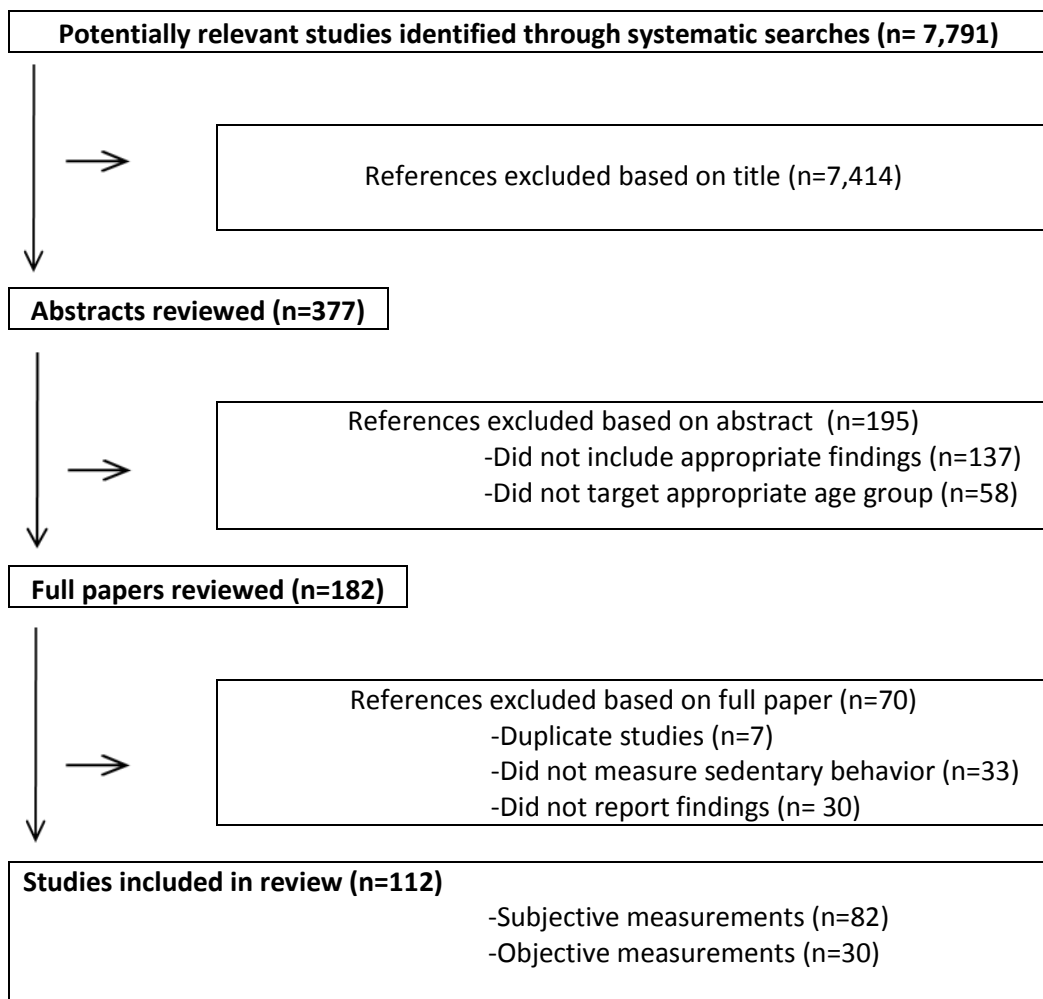


Figure 2.1. Process of exclusion and selection for subjective and objective measurements of sedentary activity

Table 2.2 outlines the selected 112 studies, which are classified by measurement method and ordered by date of publication. Any studies that objectively measured sedentary behavior but additionally used a subjective method were classified as objective measurement. Reported time spent sedentary is presented in the results column and represents the activity types measured.

Table 2.2. Subjective and objective studies that measure time spent in sedentary activity in pre-adolescent (8-15y).

Reference	Study Design	Sample Population	Measure	Objective/ Subjective	Activity Type Measured	Measurement Period	Result/Outcome (B:Boys/ G: Girls)
Karaca et al. (128)	Cross sectional	n= 916 (40%b) 14-16 years Turkey	Physical activity assessment questionnaire (PAAQ)	Subjective	<input type="checkbox"/> \wedge V	Annual recall	Mean \pm SD weekday screen-time G: 2.59 \pm 1.98/ Sat- 4.09 \pm 2.56/Sun- 3.96 B: 3.47 \pm 2.65/ Sat= 5.46 \pm 3.76/Sun= 5.38 \pm 3.80
Cameron et al. (129)	Cross sectional	n= 647 (nd%b) 5-12 years Australia	Parental proxy	Subjective	<input type="checkbox"/> \wedge V	7 day recall	Mean mins/day 141.98
Hare-Bruun, et al. (130)	Cross sectional	n= 1192(45%b) 9-10 years &14-16 years Europe	Self report questionnaire	Subjective	<input type="checkbox"/>	Before and after school recall	Mean \pm SD hours/day G: 8-10y=1.2 \pm 0.9/ 14-16y=1.5 \pm 1.1 B: 8-10y=1.4 \pm 1.1/ 14-16y=1.8 \pm 1.2
Stanley et al. (131)	Cross sectional	n= 794 (48%b) 10-14 years Australia	Self report questionnaire (MARCA)	Subjective	<input type="checkbox"/> \wedge V π \cup H Ψ ξ	4 consecutive days (3 weekdays & 1 weekend day)	Mean \pm SD mins/after school Watching TV: 11.3 Riding in a car/truck:8.8 Riding in a bus:6.2 Studying/homework:5.4 Computer/console games:4.6 Computer work:2.9 Reading:1.2 Sitting quietly:0.8 Writing:0.7 Playing cards/puzzles/board games:0.6 Arts and crafts:0.5 Mean low /high viewing G:111/100 B:89/125
Martinez-Gomez, et al.(132)	Cross sectional	n= 425 (49%b) 13-18.5 years Spain	Self report questionnaire	Subjective	<input type="checkbox"/>	Daily recall	2+h TV (13y) B:70% G: 69% 2+h TV (15y) B:69% G: 67%
Guthold et al. (133)	Cross sectional	n= 72,845 (48%b) 13-15 years 34 countries	Self report questionnaire (PACE+)	Subjective	<input type="checkbox"/> \wedge V ξ 0	7 day recall	Mean \pm SD hours/day TV: B:2.49 \pm 1.53/ G:2.6 \pm 1.43 Games: B: 2.11 \pm 1.86 G:0.54 \pm 1.08g PC:B:1.94 \pm 1.75 G:2.1 \pm 1.63g
Melkevik et al. (134)	Cross sectional	n= 4848 (52%b) 13 & 15-16 years Norway	Self report questionnaire	Subjective	<input type="checkbox"/> \wedge V	7 day recall	

Liu et al. (135)	Experimental	n= 95 (64%b) 11 & 15 years China	Self report questionnaire (HBSC)	Subjective	<input type="checkbox"/> \wedge V H ∞	Hours per day recall	ICC (95% CI) TV: school days 0.72 0.61-0.81 /weekends 0.74 0.63-0.83 Video games: school days 0.54 0.38-0.67 /weekends 0.69 0.57-0.78 Computer: school days 0.33 0.14-0.50 /weekends 0.50 0.33-0.64 Homework: school days 0.78 0.68-0.85 /weekends 0.73 0.62-0.82 No of children participating: TV viewing: Low (<2 h/day):6456 High (>2 h/day):2822 Internet use: Low (<20 h/week):7609 High (>20 h/week):1669 Median (25 th -75 th percentile) mins/day B: 480 (330-660) G: 510 (360-660)
Yen et al. (136)	Cross sectional	n= 9278 (49%b) 12-17 years Taiwan	Self report questionnaire	Subjective	<input type="checkbox"/> \wedge V	30 day recall	Mean \pm SE hours/day 3.3 \pm .15
Liou et al. (137)	Cross Sectional	n= 8640 (51.7%b) 13-16 years Taiwan	Self report questionnaire	Subjective	<input type="checkbox"/> \wedge V ψ ∞ H	Weekday/weekend day recall	Means (95% CI) mins/day weekday vs weekend TV viewing: 100.3 (92.9-107.7) 173.5 (158.9-188.0) Homework: 78.1 (73.1-83.2) 73.5 (63.8-83.1) Sitting/talking: 34.2 (30.0- 38.5) 61.0 (51.6, 70.5) Using computer: 7.6 (5.3-9.8) 11.7 (7.6-15.9) Reading: 12.0 (9.5-14.5) 24.6 (17.7-31.4) Playing computer: 25.6 (21.1- 30.2) 55.1 (45.4 -64.7)
He et al. (138)	Cross Sectional	n= 508 (49%b) 10-12 years Canada	Self administered questionnaire (CSAQ)	Subjective	<input type="checkbox"/> \wedge V	Weekly recall	Mean \pm SD hours/day M: 49.4 \pm 1.2 F:45.0 \pm 1.6
Hamar et al. (57)	Cross sectional	n= 301 (40%b) 13-18 years Hungary	Ecological momentary assessment	Subjective	<input type="checkbox"/> \wedge V H ∞ ∞	3 consecutive days &1 weekend day	Mean \pm SD mins/day F: 151.9 \pm 107.77 M: 160.26 \pm 109.88
Sisson et al. (139)	Cross sectional	n= 8707 (51%b) 2-15 years USA	Self report questionnaire	Subjective	<input type="checkbox"/> \wedge V	30 day recall	Mean \pm SD mins/day M: 156.13 \pm 74.58 F: 121.08 \pm 66.49 Socializing Beh M: 27.85 \pm 35.09 F: 38.19 \pm 34.92
Fulton et al. (140)	Longitudinal	n= 678 (51%b) 8-14 years USA	Self report questionnaire	Subjective	<input type="checkbox"/> \wedge ψ	24h recall	
Aires et al. (141)	Longitudinal	n= 345 (43%b) 11-19 years Portugal	Self report questionnaire	Subjective	<input type="checkbox"/> \wedge	24h recall + weekend	
Biddle et al. (68)	Randomized	n= 623 (40%b) 14-16 years Hungary, Romania, Slovakia	Ecological momentary assessment	Subjective	<input type="checkbox"/> \wedge V 0 ∞	4 consecutive days (3 weekdays days & 1 weekend day)	

Biddle et al. (142)	Cross sectional	n= 991(39%b) 13-14 years Scotland	Ecological momentary assessment	Subjective	$\square \wedge \vee$ $\psi \pi$	3 consecutive days &1 weekend day	Mean (95% CI) mins/day weekday/ weekend day Boys: Watching TV: 118.5 (102.2/134.7) 168.1 (133.5/202.7) Using computer: 12.7 (8.5/16.9) 22.0 (4.0/39.9) Playing computer: 27.3 (19.8/34.9) 57.9 (41.2/74.5) Sitting/talking: 16.2 (12.7/19.7) 42.1 (28.2/56.1) Homework: 32.3 (25.1/3.6) 18.1 (6.6/29.6) Reading: 8.6 (6.1/11.1) 4.5 (2.0/7.1) Sitting: 0.8 (0.3/1.4) 1.8 (0.3/3.4) Girls: Watching TV: 111.9 (101.6/122.3) 149.5 (118.9/180.2) Using computer: 16.2 (11.2/21.2) 18.8 (12.0/25.7) Playing computer: 3.6 (1.5/5.6) 6.1 (2.5/9.6) Sitting/talking: 30.3 (23.3/37.4) 68.9 (55.8/82.0) Homework: 45.3 (29.7/60.9) 36.4 (14.4/58.4) Reading: 10.3 (6.2/14.4) 12.8 (8.7/17.0) Sitting: 1.3 (0.7/1.9) 2.3 (1.1/3.4)
Wong et al. (143)	Cross sectional	n= 25,060 (51%b) 14-18 years Canada	Self report questionnaire	Subjective	$\square \wedge \vee$	Weekly recall	Mean \pm SD hours/day 2.7 \pm 1.7
Lobelo et al. (144)	Cross sectional	n= 437(0%b) 3-15 years USA	Self report questionnaire	Subjective	$\square \wedge \vee$	3 day recall	2+ hrs exposure = low PA and CRF levels.
Biddle et al. (145)	Cross sectional	n= 1484(38%b) 9-16 years England, Northern Ireland, Scotland, Wales	Ecological momentary assessment	Subjective	$\square \wedge \vee$ $\cup \text{H} \psi$ 0 π	4 day recall including 1 weekend day	Mean total leisure time SB mins/day B: weekday:234 weekend:527 G:weekday:331 weekend: 512
Lajous et al. (146)	Cross sectional	n= 9132(38%b) 11-18 years Mexico	Self report questionnaire	Subjective	$\square \vee$	Hours per day recall including weekends	Mean \pm SD hours/day B: 5.9 \pm 3.0 G: 5.4 \pm 3.0
Anderson et al. (147)	Cross sectional	2964 (51%b) 4-11 years USA	Parental proxy	Subjective	$\square \wedge \vee$	30 day recall	Mean (95% CI) hours/ week (9-11y) G:TV: 2.4 (2.2 – 2.5) Computer: 0.8 (0.7 – 0.9) B:TV: 2.4 (2.2–2.6) Computer: 1.2 (1.0 – 1.4)
Laurson et al. (148)	Cross sectional	n= 709 (45%b) 7-12 years USA	Self report questionnaire	Subjective	$\square \wedge \vee$	Daily recall including weekend	Mean \pm SD hours/day B: 4.5 \pm 3.4 G: 3.5 \pm 2.6
Eisenmann et al. (149)	Cross sectional	n= 12464 (49%b) 14–18 years USA	Self report questionnaire	Subjective	\square	School day recall	Mean (95% CI) <1 h per day TV (%) B: 34.8 (33.0–36.6) G: 41.7 (38.8–44.6) 2–3 h per day TV (%)B: 41.9 (40.0–43.7) G: 39.5 (37.7–41.5) >4 h per day TV (%)B: 23.3 (21.4–25.4) G: 18.3 (16.8–21.0)

Mark et al. (150)	Cross sectional	n= 1803 (56%b) 12-19 years USA	Self report computerized questionnaire	Subjective	<input type="checkbox"/> \wedge V	30 day recall	Mean \pm SD hours/day G: 2.9 ± 2.0 B: 3.1 ± 2.0
Haerens et al. (151)	Cross sectional	n= 534 (37%) 12-14 years Belgium	Self report questionnaire	Subjective	<input type="checkbox"/>	Daily recall including weekend	Viewing habits/fat intake β (95% CI) Block 1:0.05 (8.15, 3.82) Block 2:0.15(1.43, 8.97)
Henderson (152)	Cross sectional	n= 2,379 (0%b) 9-10 years USA	Self-reported questionnaire	Subjective	<input type="checkbox"/>	1 week recall	Mean \pm SD hours/day White girls: 3.59 ± 2.06 Black girls: 5.21 ± 2.55
Must et al. (153)	Prospective cohort	n= 196 (0%b) 8-12 years USA	Self report questionnaire	Subjective	<input type="checkbox"/> \wedge V	School day and weekend day recall	Mean \pm SD hours/day = 3.4 ± 2.4
Taveras et al. (154)	Cross sectional	n= 10856 (41%b) 10-15 years USA	Self report questionnaire	Subjective	<input type="checkbox"/> \wedge V	7 day recall	Mean \pm SD hours/week B: 11.6 ± 8.1 G: 9.8 ± 7.6
te Velde et al. (155)	Cross sectional	n= 12583(44%b) 11 years Austria, Belgium, Denmark, Iceland, the Netherlands, Norway, Portugal, Spain, Sweden	Self report questionnaire	Subjective	<input type="checkbox"/> \wedge V	Hours per day recall	TV viewing > 2 hours/day B: 2.5 ± 1.7 h/day G: 2.2 ± 1.6 h/day
Gorely et al. (69)	Randomized	n= 1604 (38%b) 13-15 years England, Northern Ireland, Scotland, Wales	Ecological momentary assessment	Subjective	<input type="checkbox"/> \wedge V H 0 ∞	4 consecutive days (3 weekdays days & 1 weekend day)	Mean range 5 clusters mins/day Computer use: B:31.6 \pm 148.5 G:ND Socialising behaviors: B: 28.2 \pm 119.9 G:62.3 \pm 153.8 TV/Video: B: 113.6 \pm 222.3 G:90.9 \pm 190.9 Homework: B:36.1 \pm 117.9 G:35.5 \pm 102.0 Working: B:ND G:12.0 \pm 101.1
Brodersen et al. (156)	Longitudinal	n= 5287 (49%b) 11-12 years England	Self report questionnaire	Subjective	<input type="checkbox"/> \wedge V	7 day recall	Mean \pm SE hours/week 2.52 ± 0.066
Ortega et al. (157)	Cross sectional	n= 2859 (53%b) 13-18 years Spain	Self report questionnaire	Subjective	<input type="checkbox"/> \wedge V	1 day recall	Mean \pm SD hours/day M: 2.58 ± 1.56 F: 2.11 ± 1.31
Scully et al. (158)	Cross sectional	n= 18,486 (46%b) 12-17 years Australia	Self report questionnaire	Subjective	<input type="checkbox"/> \wedge V H	7 day recall	Mean % hours/school day ≥ 2 homework 32.7% ≤ 2 TV 65.2% ≤ 2 internet/PC= 75.4% \leq Electronic media=29.15%
Shapiro et al. (159)	Randomized Psychoeducational intervention	n= 58 (38%b) 5-13 years North Carolina, USA	Self report questionnaire	Subjective	<input type="checkbox"/> \wedge V	Daily recall	Mean \pm SD mins/day(baseline) SMS:149.3 \pm 90.0 Paper diary:200.5 \pm 158.8 Control:188.6 \pm 197.1
Zambinski et al. (160)	Cross sectional	n= 878 (48%b) 11-15 years San Diego, CA	Self report computerized questionnaire	Subjective	<input type="checkbox"/> \wedge V H ψ 0 π	24 h recall & weekend day	Mean \pm SD hours/day Watching TV, videos, or DVDs: 2.1 ± 1.5 Playing computer games: 1.0 ± 1.3 Sitting while listening to music: 1.0 ± 1.3 Sitting while talking on the phone: 0.8 ± 1.3 Doing homework: 1.5 ± 1.2 Reading: 0.7 ± 1.1

Olds et al. (161)	Cross sectional	n= 1039 (52%b) 10-13 years Australia	Self report questionnaire (MARCA)	Subjective	<input type="checkbox"/> \wedge \vee	24 hour recall	Mean mins/day B:264 G:196
Mark et al. (162)	Cross sectional	n= 6942 (46%b) 11-16 years 35 countries	Self report computerized questionnaire	Subjective	<input type="checkbox"/> \wedge \vee	Daily recall including weekend days	Mean hours/day G: 1.50 B: 1.79
Hardy et al. (163)	Cross sectional	n= 2750 (nd%b) 10-15 years Australia	Self report questionnaire (ASAQ)	Subjective	<input type="checkbox"/> \wedge \vee	Before and after school weekly recall	Mean hours/day Primary: 2.2 Secondary: 2.8
Nelson et al. (164)	Longitudinal	n= 2516 (45%b) 11-18 years USA	Self report questionnaire (EAT 1 & EAT11)	Subjective	<input type="checkbox"/> \wedge \vee	Average weekday recall	Mean \pm SE hours/week M: 20.0 \pm 0.7 F:22.5 \pm 0.8
Chamberlain et al. (165)	Cross sectional	n= 827 (48%b) 8-9 years USA	Self report questionnaire	Subjective	<input type="checkbox"/> \wedge \vee	24h recall and previous Saturday	Mean \pm SD hours/week (baseline) 22.8 \pm 24.7
Harrison et al. (166)	Intervention	n= 130 (58%b) 9-10 years Ireland	Self report questionnaire (PDPAR)	Subjective	<input type="checkbox"/> \wedge \vee	24h recall including a Sunday	Mean \pm S.E (control group) 30 min blocks/day) Control: 5.97 (0.25)
Hakala et al. (167)	Cross sectional	n= 6003 (44%b) 14 & 16 & 18 years Finland	Self report questionnaire	Subjective	<input type="checkbox"/> \wedge	Weekdays	Adjusted odds ratio >2-3 h/day: 1.3 4-5 h/day: 1.8
Pate et al. (168)	Cross sectional	n= 3287 (51%b) (12 -19 y) USA	Self report questionnaire	Subjective	<input type="checkbox"/> \wedge \vee	24 h recall	Mean \pm SE hours/day Males:, 46.4 \pm 0.4.Females: 38.7 \pm 0.3
Salmon et al. (99)	Cross sectional	n= 947 (46%b) 10-12 years Australia	Self report questionnaire	Subjective	<input type="checkbox"/>	7-14 day recall	Television viewing (> 2 h/day) B: n=425 G: n=497
Utter et al. (169)	Cross sectional	n= 972(53%b) 11-14 years New Zealand	Self report questionnaire (FFQ)	Subjective	<input type="checkbox"/> \vee	7 day recall	Odds ratio (95% CI) <1h: Overweight= 1.0 Obese= 1.0 1 to <2h: Overweight=1.1 (0.7-1.8) Obese= 2.1 (1.1-4.1) >2h: Overweight=1.1 (0.7-1.8) Obese= 2.9 (1.5-5.7)
Iannotti et al. (170)	Cross sectional	n= 49124 (nd%) 11 & 13 & 15 years North America, Canada, Switzerland, Netherlands, Czech Republic, Poland, Finland, Norway, Italy, Spain.	Self report questionnaire	Subjective	<input type="checkbox"/> \wedge \vee	24h recall including weekend	Mean \pm SD hours/day North America: 4.1 \pm 2.9 Western Europe: 3.7 \pm 2.7 Eastern Europe: 4.3 \pm 2.8 Northern Europe: 3.6 \pm 2.3 Southern Europe: 3.5 \pm 2.3

Elgar et al. (24)	Cohort study	n= 355 (ND%) 6-18 years Wales	Self report questionnaire (HBSC)	Subjective	<input type="checkbox"/> \wedge V	Hours per day recall	Mean \pm SD hours/week Y 7: Underweight: 29.61 \pm 15.48 Normal: 27.49 \pm 15.71 Overweight: 27.61 \pm 14.88 Obese: 29.17 \pm 15.30 Y11: Underweight: 27.79 \pm 17.52 Normal: 29.27 \pm 17.24 Overweight: 28.33 \pm 13.98 Obese: 27.81 \pm 15.73
Murdy et al. (171)	Longitudinal	n= 83 (52%b) 12-15 years England	Ecological momentary assessment	Subjective	<input type="checkbox"/> \wedge V ∞ H ψ 0 π ∞	3 consecutive days &1 weekend day (minus school hrs).	Mean \pm SE mins/day Weekday: M: 224.11 \pm 71.47 F: 240.33 \pm 67.80 Weekend: M:398.10 \pm 157.71 F: 337.99 \pm 138.79
Norman et al. (172)	Cross sectional	n= 878 (46%b) 11-15 years USA	Computerized Self report questionnaire	Subjective	<input type="checkbox"/> \wedge V ψ π 0	Non-school day recall	Mean \pm SD mins/day G: 300 \pm 223 B: 286 \pm 218
Salmon et al. (173)	Cross sectional	n= 878 (49%b) 10-12 years Australia	Self report questionnaire and parental questionnaire	Subjective	<input type="checkbox"/> \wedge V π	8 day recall	Mean \pm SD mins/day TV viewing: 130.7 \pm 68.9 Computer or internet: 26.3 \pm 34.7 Electronic games: 33.1 \pm 45.0
Hancox et al. (174)	Longitudinal	n= 1037 (52%b) 0-26 years New Zealand	Parental proxy	Subjective	<input type="checkbox"/>	Weekday/weekend day recall	Mean \pm SD hours/day 9y B:2.22 \pm 1.03 G:2.04 \pm 1.03 11y B: 2.60 \pm 1.16 G:2.41 \pm 1.12 13y B: 3.86 \pm 1.57 G:3.54 \pm 1.48 15y B: 3.58 \pm 1.79 G:3.19 \pm 1.71
Klein-Platat et al. (175)	Cross sectional	n= 2714 (50%b) 12 years France	Self report questionnaire	Subjective	<input type="checkbox"/> \wedge V ψ	Daily recall	Mean \pm SD hours/week G:1.21 \pm 1.52 B:1.13 \pm 1.19
Stettler et al. (176)	Cross sectional	n= 872 (53%b) 7-9 years Switzerland	Self report questionnaire	Subjective	<input type="checkbox"/> V	Weekday recall	Odds ratio (95% CI) Electronic games: 2.03 (1.57-2.61) TV viewing: 2.83 (2.08-3.86)
Murdy et al. (70)	Cross sectional	n= 79 (53%b) 12-14 years Leicestershire	Ecological momentary assessment	Subjective	<input type="checkbox"/> ∞ \wedge π ∞	3 consecutive days	Mean \pm SD mins/day M: 212 \pm 68.19 F: 234.66 \pm 66.71
Schmitz et al. (177)	Reliability study	n= 245 (41%) 11-15 years USA	Self report survey	Subjective	<input type="checkbox"/> \wedge V	Not stated	Mean \pm SD hours/day Television viewing G: 2.3 \pm 1.3 B: 2.3 \pm 1.3 Computer use G: 1.6 \pm 1.2 B: 1.3 \pm 1.2

Treuth et al. (178)	Longitudinal	n= 91 (0%b) 8-10 years USA	Parental proxy questionnaire	Subjective	<input type="checkbox"/>	Annual recall	Mean \pm SD hours/day During school yr 8y:1.4 \pm 0.9 9y:1.4 \pm 1.0 10y:1.3 \pm 0.9 During summer 8y:2.3 \pm 1.6 9y:2.5 \pm 1.8 10y: 2.3 \pm 1.8 Mean \pm SD mins/non school days G:128.65 \pm 93.02 B:124.95 \pm 72.90
Patrick et al. (179)	Randomized control trial	n= 878 (45%b) 11-15 years San Diego, USA	Self report questionnaire	Subjective	<input type="checkbox"/>	7 day recall	Mean% hours/day 3.5 =57.2 >3.5 =42.8
Grimm et al. (180)	Cross sectional	n= 560 (51%) 8-13 years USA	Self report survey	Subjective	<input type="checkbox"/>	Weekend and Weekdays	Odds ratio (95% CI) Obesity 1: Video: 1.10 (0.93-1.30) TV: 2-3 h- 1.03 (0.85-1.25) TV: 3-5 h-1.61 (1.31-1.70) Obesity 111: Video: 1.13 (0.96-1.34) TV: 2-3 h- 0.98 (0.81-1.18) TV: 3-5 h-1.51 (1.22-1.87) Overweight 1: Video:1.17 (1.04-1.30) TV: 2-3 h- 1.19 (1.05-1.34) TV: 3-5 h-1.44 (1.25-1.67) Overweight 111: Video: 1.19 (1.07-1.33) TV: 2-3 h- 1.15 (1.02-1.30) TV: 3-5 h-1.36 (1.18-1.58)
Tremblay et al. (181)	Cross sectional	n= 7216 (nd/%) 7-11 years Canada	Parental proxy questionnaire	Subjective	<input type="checkbox"/> \wedge \vee	Annual Recall	Mean \pm SD <1.75 h: 18.7 \pm 0.6 1.75 to <3.0 h: 19.6 \pm 0.4 3.0+ h: 20.7 \pm 0.7 Mean \pm SD hours/day = 3.32 \pm 2.10
Proctor et al. (182)	Longitudinal	n= 94 (nd/%) 10-12 years USA	Parental proxy	Subjective	<input type="checkbox"/> \vee	3 to 5 day recall	Mean hours/night television viewing G:1.9 B:1.8
Boynton-Jarrett et al. (183)	Cross sectional	n= 548 (52%b) 10-12 years USA	Self report questionnaire	Subjective	<input type="checkbox"/>	30 Days	Mean hours/week TV B:15.7 G:14.8 Video game/computer B:5.7 G:3.6
Giammattei et al. (184)	Cross sectional	n= 385 (48%b) 11-13 years USA	Self report questionnaire	Subjective	<input type="checkbox"/> \wedge \vee	School night recall	Mean hours/week TV B:15.7 G:14.8 Video game/computer B:5.7 G:3.6
Wake et al. (185)	Cross sectional	n= 2862 (51%b) 5-13 years Australia	Parental proxy	Subjective	<input type="checkbox"/> \wedge \vee	School day and non-school day recall	Mean hours/week TV B:15.7 G:14.8 Video game/computer B:5.7 G:3.6
Saelens et al. (186)	Cross sectional	n= 228 (51%b) 11-12 years USA	Parental proxy and self report questionnaire	Subjective	<input type="checkbox"/>	1 day recall and weekend recall	Mean hours/week Parental proxy:25.0 Self report:27.6.

Lowry et al. (187)	Cross sectional	n= 15394 (48%b) 14-18 years USA	Self report questionnaire	Subjective	□	Daily average recall	Mean % (95% CI) <2h Grade 9:49.0 (44.2-53.8) Grade 10: 53.7 (49.1-58.3) 3-4h Grade 9:32.3 (28.5-36.1) Grade 10: 31.1 (28.4-33.8) >5h Grade 9:18.7 (14.3-23.0) Grade 10:15.3 (11.3-19.2) Mean ± SD hours/day 2.5 ± 1.3
Özmert et al. (188)	Cross sectional	n= 885 (50%b) 7-8 years Turkey	Self report parental questionnaire	Subjective	□	24h recall for 7 days	Mean hours/day =2.5
Ho et al. (189)	Cross sectional	2110 (52%b) 12-14 years Hong Kong	Self report questionnaire	Subjective	∧	Daily recall	Mean hours/day =2.5
Crespo et al. (190)	Cross sectional.	n= 4069 (49%) 8-16 years USA	Self report questionnaire	Subjective	□	5 day recall	Odds ratio (95% CI) <1B: 1.0 (. . .) G: 1.0 (. . .) 2B: 1.40 (0.67-2.92) G: 1.18 (0.71-1.95) 3B: 1.57 (0.79-3.13) G: 2.83 (1.29-6.24) 4B: 1.72 (0.79-3.74) G: 3.85 (1.75-8.46) >5B: 2.63 (1.01-6.85) G: 2.53 (1.01-6.36) All-day sedentary Y: 0.7/ N:99.3 Leisure time sedentary Y:31.3/ N:68.7
Kristjansdottir et al. (95)	Randomized control trial	n= 3270 (51%b) 11-16 years Iceland	Self report questionnaire	Subjective	π ∞	Not stated	
Janz et al. (191)	Longitudinal	n= 126 (48%b) 9-15 years USA	TV/Video Game Recall questionnaire	Subjective	□ V	1 day recall	Mean ± SD mins/day B: 67.5 ± 172.5 G: 63.8± 131.0
Roberts et al. (192)	Cross sectional	n= 2065 (nd%b) 8-18 years USA	Self report questionnaire	Subjective	□ ∧ V	1 week recall	Mean % total time sedentary 8-13y: 44% 14-18y: 36%
McMurray et al. (193)	Longitudinal	n= 2389 (48%b) 10-16 years USA	Self report questionnaire	Subjective	π ψ □ V	Weekly recall	TV 2h+ /day B: school days- 56% G: school days -51% Mean % viewing video game B: school days- 69%/non school day- 79% . G: schools days-35%/ non school day-50%
Berkey et al. (194)	Longitudinal	n= 10769 (43%b) 9-14 years USA	Self report questionnaire	Subjective	□ ∧ V	Hours per day recall including weekend days	TV/games hours/day G:3.42 to 3.86 B: 4.15 to 4.80
Hernandez et al. (195)	Cross sectional	n= 461 (53%) 9-16 years Mexico	Self report questionnaire	Subjective	□ V	Daily recall including weekend days	Mean ± SD hours/day 4.1 ± 2.2 hours

Anderson et al. (196)	Cross sectional	n= 4063 (49%b) 8-16 years USA	Self report questionnaire	Subjective	<input type="checkbox"/>	Daily	Mean ± SE B: <1 h Daily=36.3 (1.1) 2-3 h Daily=34.8 (1.3) >4 h Daily=28.9 (1.0) G: <1 h Daily=41.9 (1.42) 2-3 h Daily=35.3 (1.2) >4 h Daily=22.7 (1.1) OR (95% CI) Low socio economic G:3.4 (CI 2.6-4.2) B:3.7 (CI 2.9-4.5) High socio economic G:1.5 (O 1.1-2.0) B:2.2 (CI 1.7-2.6)
Gracey et al. (197)	Cross sectional	n= 391 (51%b) 15 years Australia	Self report questionnaire	Subjective	<input type="checkbox"/>	Weekday and Weekend recall	Mean ± SD hours/after school TV viewing 2.51 ±1.52
Robinson et al. (198)	Longitudinal	n= 279 (0%b) 11-13 years USA	Self report questionnaire	Subjective	<input type="checkbox"/>	After school recall	Mean ± SD hours/day 2-4: <200mg/dl: 31 ±307 >200mg/dl: 45± 39 >4: <200mg/dl: 3 ± 33 >200mg/dl: 8± 7
Wong et al. (199)	Cross sectional	n= 1081 (51%b) 2-20 years USA	Parental proxy	Subjective	<input type="checkbox"/> V	Daily recall	Mean ± SD hours/day 3.5 ±2.2
Robinson (200)	Intervention	n=1295 (52%b) 11-12 years USA	Self report questionnaire	Subjective	<input type="checkbox"/> V	Weekly recall	Mean ± SD hours/week Television: 15.46 ± 15.02 Video tapes: 5.52 ± 10.44 Video games: 3.85 ± 9.17 h/d mean: 4.2
Gortmaker et al. (201)	Intervention	n=192 (45%b) 8-9 years USA	Self report questionnaire	Subjective	<input type="checkbox"/> V	Weekly recall	Mean (95% CI) mins/day G:349.3 (339.1, 359.4) B: 338.5 (318.8, 358.2)
Gortmaker et al. (202)	Intervention	n=479 (29%b) 8-10 years USA	Self report questionnaire	Subjective	<input type="checkbox"/>	24 hour recall	Mean ± SD % of time= 50.8 (42.1-58.9)
Affuso et al. (203)	Feasibility	n= 190 (38%b) 11-15 years USA	ActiGraph accelerometer and self-reported questionnaire (TAAG)	Objective	≠	3 days	Mean ± SD % time 81.1 ± (76.8–84.4)
Carson et al. (204)	Cross sectional	n= 2572 (50%b) 10-16 years USA	ActiGraph accelerometer and self report questionnaire	Objective	≠	7 day (including 1 weekend)	Mean + SD hours/ day 12.5- 13.49y= B- 13.8 ± 1.6 G-13.6 ± 1.6 13.5-14.49y= B- 13.5 ±1.2 G- 13.2 ± 1.3
Basterfield et al. (205)	Longitudinal	n= 405 (48%b) 9 years England	ActiGraph accelerometer	Objective	≠	Min 3 days	
Ruiz et al. (206)	Cross sectional	n= 1808 (46%b) 12.5–17.5 years Athens, Dortmund, Ghent, Heraklion, Lille, Pecs, Rome, Stockholm, Vienna and Zaragoza	ActiGraph accelerometer	Objective	≠	7 consecutive days	

Colley et al. (15)	Cross sectional	n= 1608 (50%b) 6-19 years Canada	ActiCal accelerometer	Objective	≠	5 weekdays & 2 weekend days	Mean ± SD mins/day B: 507 ± 56.3 G:524 ± 68
Epstein et al. (16)	Intervention	n= 56 (48%b) 8-12 years USA	TV Allowance™ device and daily habit books	Objective	□ ∧ V	2 weekdays and 1 weekend day	Mean ± SEM hours/week 34.9 ± 1.7 TV viewing: 24.9 ± 1.7 Computer games 5.5 ± 0.8
Steele et al. (207)	Cross sectional	n= 1568 (44%b) 9-10 years United Kingdom	ActiGraph accelerometer	Objective	≠	Min 3 days (including 1 weekend) 3 days data	Mean ± SD mins/day M:450.4 ±56.5 F:462.7 ± 52.0
Jago et al. (208)	Cluster analysis	n= 761 (57%b) 10-11 years England	ActiGraph accelerometer and self report questionnaire	Objective	≠		Coefficient (95% CI) Weekday High Active/High Sed: 14.11 (-0.08 to 28.31) Low Active/Med Sed: 10.06 (1.99 to 18.12)
Page et al. (209)	Cross sectional	n= 1013 (46%b) 10-11 years England	ActiGraph accelerometer and strengths and difficulties questionnaire	Objective	□ ∧	7 days	Mean ± SD mins/day B:465.9 ± 57.3 G:494.8 ± 58.0
Martinez-Gomez et al. (210)	Cross sectional	n= 201 (50%b) 13–17 years Spain	ActiGraph accelerometer and self-reported questionnaire (TAAG)	Objective	≠	Min 4 days	Mean ± SD mins/day B: 494 ± 72 G: 470 ± 76
Steele et al. (211)	Cross sectional	n= 1862 (44%b) 9-10 years United Kingdom	ActiGraph accelerometer	Objective	≠	7 consecutive days	Mean ± SD mins/week M:450 ± 56.2 F:461 ± 51.63
Purslow et al. (212)	Cross sectional	n= 345(51%b) 8-9 years London	ActiGraph accelerometer	Objective	≠	5 consecutive days including 2 weekend days	Mean ± SD mins/day 330 ± 119
Nilsson et al. (213)	Cross sectional	n= 1327 (46%b) 9 & 15 years Denmark, Portugal, Estonia, Norway	ActiGraph accelerometer	Objective	≠	2 weekdays and 2 weekend days	Mean ± SD mins/day 9y:Weekday: G:318.5±71.5 /B:301 ± 76.5 Weekend: G:274±84.5 /B:275±87.7 15y:Weekday: G:450.5±87 /B:424.5 ± 88 Weekend: G:383±88.7 /B:386±90.2
Mitchell et al. (11)	Cross sectional	n= 5434 (47%b) 11-12 years United Kingdom	ActiGraph accelerometer	Objective	≠	Min 3 days	Mean ± SD mins/day Males 417.9 ± 67.7 Females 436.5 ± 64.0
Martinez-Gomez et al. (214)	Cross Sectional	n= 214 (50%b) 13-16 years Spain	ActiGraph accelerometer	Objective	≠	7 consecutive days	Mean ± SD mins/day B: 496.12 ± 80.64 G: 471.38 ± 84.34
Matthews et al. (215)	Cross sectional	n= 886 (52%) 12-19 years USA	ActiGraph accelerometer	Objective	≠	7 consecutive days	Mean ± 95% CI hours/day 7.53 (0.10)
Sardinha et al. (216)	Cross sectional	308 (52%b) 9-10 years Portugal	ActiGraph accelerometer	Objective	≠	4 days	Mean ± SD mins/day 315 + 90
Maloney et al. (217)	Cross sectional	n= 60 (50%b) 7-8 years USA	ActiGraph accelerometer and co-report survey (parent/child)	Objective	≠	7 consecutive days	Mean ± SD mins/day 292.0 (62.0)

van Sluijs et al. (218)	Cross sectional	n= 2107 (50%b) 9-10 & 14-15 years Denmark, Estonia, Portugal, Norway	ActiGraph accelerometer	Objective	≠	4 days (2 weekday/ 2 weekend day)	Mean ± SD mins/day 262 ± 99.7
Kriemler et al. (219)	Cross sectional	n= 269 (47%b) 10-11 years Switzerland	ActiGraph accelerometer	Objective	≠	7 consecutive days	Mean ± SD mins/day B:554 ± 70.8 G:586 ± 59.7
Jago et al. (220)	Cross sectional	n= 447 (100%b) 10-14 years Houston	ActiGraph accelerometer and self report questionnaire	Objective	≠	3 days	Mean ± SD mins/day 917.40± 53.37
Treuth et al. (221)	Cross sectional	n= 1603 (0%b) 11-12 years USA	ActiGraph accelerometer	Objective		6 days	Mean ± SD mins/day Weekday= 501 ±70 Weekend=359 ±96
Hardy et al. (222)	Longitudinal	n= 163 (0%b) 12-15 years Australia	ActiGraph accelerometer and self report questionnaire	Objective	≠	7 consecutive days	Mean ± SD hour/week 34.8 ± 12.4
Epstein et al. (223)	Crossover	n= 58 (48%b) 8-15 years USA	Brutech event logger & Self report habit book	Objective	□ ∧ V	3 consecutive days	Mean ± SD mins/day 189.1 ±163.0
Pate et al. (224)	Cross sectional	n= 1721 (0%b) 13-14 years USA	ActiGraph accelerometer	Objective	≠	6 consecutive days	Mean ± SE mins/day 460 ± 5.8
Jago et al. (225)	Cross sectional	n= 81 (45%b) 13-14 years USA	ActiGraph accelerometer	Objective	≠	4 days	Mean ± SD mins/hour Thursday: 6am-3pm B:52.6 ± 3.4 G: 56.3 ± 4.2 3pm-7pm B:48.4 ± 7.6 G:55.2 ± 6.2 7pm- 12am B:54.2 ± 4.2 G:55.7 ± 5.2 Friday: 6am-3pm B:51.5 ± 2.6 G:53.6 ± 3.1 3pm-7pm B:44.6 ± 9.3 G:51.1 ± 5.8 7pm- 12am B:50.8 ± 6.7 G:52.1 ± 6.2 Saturday: 6am-3pm B:52.2 ± 6.5 G:57.6 ± 2.9 3pm-7pm B:47.7 ± 9.3 G:55.5 ± 7.2 7pm- 12am B:52.8 ± 5.2 G:56.2 ± 4.4 Sunday: 6am-3pm B:52.8 ± 5.1 G:55.2 ± 2.8 3pm-7pm B:49.8 ± 6.3 G:49.7 ± 7.3 7pm- 12am B:53.0 ± 5.1 G:54.6 ± 4.9
Johnson et al. (226)	Cross sectional	n= 1712(0%b) 11-12 years USA	ActiGraph accelerometer	Objective	≠	6 days	Mean ± SD mins/day 342.33± 57.9
Epstein et al. (227)	Crossover	n= 16 (50%b) 12-16 years USA	Brutech event logger and self report questionnaire	Objective	□ ∧	2 weekdays and 1 weekend	Mean ± SD mins/day F: 175.1 ± 51.1 M: 180.5 ± 72.0

Nilsson et al. (228)	Cross sectional	n= 1954 9 & 15 years Denmark, Estonia, Portugal, Norway	ActiGraph accelerometer	Objective	≠	4 consecutive days including 2 weekend days	Mean ± SD mins/day (weekday & weekend) Denmark G:309 ±75 208 ±87 B:311 ±78 299 ±87 Portugal G:344 ±75 279 ±97 B:318 ±81 269 ±89 Norway G: 314 ±62 280 ±75 B:289 ±70 298 ±81 Estonia G: 307 ±75 257 ±80 B: 298 ±70 289 ±81
Treuth et al. (229)	Cross sectional	n= 234 (27%b) 8-16 years USA	ActiWatch accelerometer	Objective	≠	4 school & 2 weekend	Mean ± SD mins/day Primary: 435.5 ± 84.7 min Middle: 491.9 ± 84.4 min High: 543.2 ± 96.9 min.

Key □=TV viewing Λ=Computer use V= Video/movies H=Homework ⌚=Sleeping 0=Talking on the phone π=Other (i.e. hobbies/music)

∞=Travelling ψ=Reading ⌘=Quietly sitting/sitting with friends ≠=All sedentary time

How do subjective and objective measures of sedentary behavior differ in time spent being sedentary in pre-adolescents (8-15)?

Subjectively measured sedentary time

Overall time spent sedentary: Investigators from six studies have provided estimates of total time spent in sedentary behavior using self report ecological momentary assessment (EMA) diaries, which allow participants to report their behavior at a specific time using minute-by-minute recall (57, 68-70, 142). In these studies, it was reported that the most prevalent sedentary activity was television watching (57, 69). Total reported leisure sedentary time was 3.9 and 8.7 hours per day during weekdays for boys and girls, respectively. Weekend behavior was also reported at 5.6 and 8.5 hours per day for boys and girls respectively (145). Girls were noted to (70) engage in higher levels of socializing sedentary behaviors (sitting and chatting, talking on the phone) (68), while boys engaged in higher levels of screen-based sedentary behaviors (68).

Screen-based media: Chamberlain, Wang, and Robinson (165), found that children would spend on average 23 hours per week (3.3 hours per day) engaged in total screen-based activities. This finding is similar to that reported by both Taveras et al (66) (17 hours per week for boys and 23 hours per week for girls) and Olds, Ridely and Dollman (74) (21-28 hours per week). Olds and colleagues also reported 1 in 10 boys engaging in almost 7 hours per day of screen-time.

In addition to general screen-based media, investigators have also reported (using self-reported questionnaires and parental proxy reports) the time spent specifically on television viewing. Pre-adolescents will spend, on average, between 2 to 3 hours per day watching television (10, 57, 119, 146, 163, 164, 177, 196, 198, 199, 230) and on average 2.5 hours using computers (189). However, it is not uncommon for some children to spend greater than 4 hours (130, 139, 162, 195, 196, 231) and up to 7 hours (134, 161) watching television daily.

Objectively measured sedentary time

Several investigators have reported in their studies (11, 15, 205-207, 210, 219, 224, 232, 233) that pre-adolescents spend ~60-80% of their total waking time in sedentary behavior, while others have noted lower levels of time spent in sedentary behaviors i.e. 47-60% (204, 209, 213, 215, 221, 229, 234) or 30-45% (212, 213, 216-218, 226, 234) of time. Jago, Anderson, Baranowski, and Watson (225) investigated differences in sedentary activity patterns over four days, and noted children on average will spend 44 to 57 minutes per hour (70-90%) in sedentary behavior. Although this finding is higher than the studies stated above, it included a proportion of sleep time. Furthermore, after removal of school time, it was reported pre-adolescents spent between 39-46% of their time in sedentary activities, suggesting that they spend a substantial amount of time sitting at school. A novel study by Affuso, et al (203) showed that pre-adolescents spent 349 mins per day in leisure-based sedentary behavior, however leisure time was not defined, making it difficult to compare these findings with other studies in sedentary behavior.

In addition to total measured sedentary time, three studies (16, 223, 235) have shown objectively measured screen-time as a singular sedentary activity. Viewing time was quantified using event loggers to track minute-by-minute energy consumption of a screen-based electronic appliance, and although there are a number of limitations, it was estimated that pre-adolescents will spend on average between 12% and 21% of their waking time in screen-based media (3-4 hours per day).

Subjectively and objectively measured weekday and weekend time

In children, weekdays and weekend days are likely to provide different opportunities for being sedentary (228). Measuring sedentary behavior across all days of the week may add to our understanding of variations or patterns that occur in pre-adolescents behavior. Murdey, et al. (171) noted subjectively measured boys' sedentary time increased from 3 - 4.5 hours to 5.5 - 8 hours and girls' sedentary time increased from 3 - 5 hours to 4 - 7 hours over weekend days, emphasizing longer bouts of sedentary behavior during weekend days. Similarly, other studies using subjective measures showed that during weekend days boys and girls increased time spent in screen-

based activities (57, 68, 128, 142, 161, 171, 197) and television viewing in particular, increased by 1.4 - 2 hours during weekend days (128). In corroboration with studies using subjective measuring tools, studies using objectively measured sedentary time have also shown that pre-adolescents accumulate a higher mean of overall sedentary time on weekend days than on weekdays (57, 128, 197, 236). However, in contrast, several objective (11, 165, 207, 221, 225, 228) and one subjective (78) study noted that either children were more sedentary during weekdays than on weekend days or findings displayed no differences. It was noted though, pre-adolescents also spent less time in moderate to vigorous activity during weekend days and more time in light activity (221). This suggests that findings between studies may be inconclusive and further research with larger sample sizes are required when measuring differences between weekdays subjectively.

What are the associations between sedentary behavior and adiposity, food consumption and other health outcomes?

There is evidence linking the time spent in sedentary behaviors to negative health outcomes in adults, including insulin resistance, type 2 diabetes, increased body mass index and decreases in skeletal muscle (174, 236-239). Recent research also suggested that sedentary behavior is associated with increased caloric intake, which may lead to further negative health outcomes. Although the majority of sedentary behavior-related cardiovascular and metabolic research has been conducted in sedentary adult populations, the findings suggest that the negative effects of a sedentary lifestyle may begin from an early age (174, 236-239).

Sedentary activities and adiposity: Several studies have suggested there is no correlation between overall sedentary time and body weight (140, 152, 185, 195, 197, 211, 212, 218, 230, 240) in pre-adolescents. In particular, one study on females reported a negative correlation between these two variables (206). However, it has been subjectively (12, 96, 136, 149, 153, 155, 175, 176, 182, 185-187, 190, 193-196, 219, 241) and objectively (132, 210, 211, 229) demonstrated that the most prominent sedentary activity, screen-based media, has a positive association with bodyweight in pre-adolescents. Although positive associations were made, comparisons highlight

that a number of positively associated findings were weak or attenuated after adjustment for physical activity level, ethnicity and socioeconomic status (12, 163, 185, 187, 190, 193, 211). In some instances, findings showed that the relationship between high levels of television viewing and weight gain was only found in pre-adolescents who physical activityd for less than one hour per day (146, 148). In a similar study, pre-adolescents who met or exceeded the recommended physical activity guidelines (134, 143, 181), but were also high users of screen-based media, had a significantly greater association with increased weight gain (146, 149, 152, 190, 196). Such discrepancies indicate that clinical findings are unlikely to be coherent and emphasize further research is required to quantify the effect of sedentary time with bodyweight.

Longitudinal screen-based media studies have reported that associations between only weekend (236) or only weekday (174) television viewing in pre-adolescents, independently predicted adult weight. Further disparities included that screen-time viewing was positively associated with body weight, but only in girls (171, 229, 242) or only in boys (146, 148, 157, 172). Research also indicates that a higher proportion of obese children exceed the recommendations of screen-time compared with overweight or normal weight children (15, 24, 139, 160, 161, 163, 172, 190). Conversely, obese children have also been found to engage in less screen-time than underweight children (24) and overweight children (198).

Sedentary time and food consumption: The relationship between excessive time spent in sedentary behavior has also been associated with unhealthy food preferences in children (130, 181, 195, 196). Children who watch more than two hours of television per day have been reported to have very different patterns of snacking and higher food consumption than children who watch less television (151, 182), which can result in an increased calorie consumption (190). Furthermore, excessive television viewing has been associated with lower fruit consumption (99, 158, 160). Boynton-Jarrett, et al (183) found for each additional hour of television viewed per day, children's fruit and vegetable servings decreased by one every six days (after adjustment for anthropometric, demographic and dietary variables). As well as decreased healthy food intake, television viewing has been associated with increased

soft drink consumption (99, 151, 158, 169, 184) and increased fat intake (130, 151, 243). In pre-adolescents the odds of drinking soft drinks daily was twice as high in children who exceeded television viewing recommendations (151, 180).

Sedentary activities and other health outcomes: In addition to associations with increased bodyweight, time spent in sedentary behavior has been linked with other negative health outcomes. One of the demonstrated effects of sedentary behavior is metabolic dysfunction, characterized by increased plasma triacylglycerol levels, decreased levels of high-density lipoprotein (HDL) cholesterol, and decreased insulin sensitivity. Mark and Janssen (2008) reported a dose–response relationship between screen-time and metabolic syndrome in pre-adolescents. Independent of physical activity time, the odds of having metabolic syndrome (METS) were three times higher in those with at least four hours per day of screen-time compared with those with one hour or less (150, 204). This study established that even children who are regularly active remain at high risk after engaging in long periods of sedentary activity. Pre-adolescents who reported screen-times of more than 3 hours per day were approximately 2 to 3 times more likely to have METS than those with 1 hour or less. Further studies have distinguished that pre-adolescents who had a high level of sedentary behavior had less favorable systolic blood pressure, triacylglycerols and serum glucose levels (132). Sardinha, et al (216) noted time spent in sedentary behavior was significantly and positively associated with insulin resistance. Cardiovascular risks were also associated in children who engaged in substantial sedentary activity (132, 144, 168, 219). However, this has been noted for high television use, but not high levels of computer use (204), after adjustment for physical activity. Lobelo, et al (144) and Pate, Wang, et al (168) noted a positive association between sedentary time and decreased cardio-respiratory fitness which remained throughout adolescence. Longitudinal data have shown that pre-adolescents' television viewing predicted lower VO₂max, higher serum cholesterol and associations between cigarette smoking in early adults (174). It was noted that girls who engaged in sedentary activity had positive associations with low cardio-respiratory fitness (132). However girls who spent less than 69% of their time in sedentary activities had a weaker correlation than girls who spent more than 69% of their time engaged in sedentary activity.

Time spent in screen-based media has also been linked to a number of other health outcomes in children. Pre-adolescents who watched television more than 4 hours a day had 3.3 times the risk of hypertension compared with those who watched less than 2 hours a day (244). Television and computer use has also been positively associated with muscular-skeletal pain (167), psychological difficulties such as stress (209, 242), poorer self image (170) or lower self-efficacy (160, 245), anti-social behavior (188, 246), aggression (167, 170, 188, 245, 247) early sexual behaviors (245) and depression (226). Additionally, Hakala, et al. (167) Iannotti, et al (167), Iannotti, et al (170) noted a correlation between sedentary behavior and alcohol use in children aged 11-15 years. Although these health outcomes are not as predominately researched in comparison to the physiological effects of sedentary behavior, the findings provide further emphasis that time spent sedentary negatively impacts health.

DISCUSSION

Objective measurement of total time spent sedentary has reported that pre-adolescents spend, on average, between 60 - 70% of their day engaging in sedentary activities. Considering that a waking day is at least 12 hours long, on average, 7 - 8 hours per day is spent in sedentary activities. It must be noted that findings between measures are not consistent. Several objective studies have noted as little as 30 - 40% of time (3 - 5 hours) spent in sedentary behaviors (212, 213, 216-218, 226, 234). Subjective measurement also varies widely, with pre-adolescents spending 3 - 9 hours per day in sedentary behavior.

Measurement of sedentary behavior

This critical review of the literature highlights that measuring total time spent in sedentary behavior is complex. As well as methodological discrepancies in both subjective and objective assessments, covariates such as age, socio-economic status, ethnicity of participants and days of the week will have an effect on the time pre-adolescents spend sitting. While this review uncovered a proliferation of research on subjective measurement of sedentary behavior, most investigators measured time spent in selected sedentary activities, and could not provide an accurate representation of the total time spent sedentary over the course of a day. Objective

measurement provides a measurement of total time spent sedentary, but cannot easily measure time spent in specific sedentary activities, which may limit our understanding of sedentary activity preference.

To highlight the discrepancies between methods of measurement, male pre-adolescents' self-reported total sedentary activity is 294.6min per day; however accelerometer data reported that, on average, boys would spend 917.4min per day in sedentary activity (220). These findings illustrate that quantifying sedentary time through self-recalling of specific sedentary activities, will often underestimate overall time spent in sedentary behavior; self-reporting pre-adolescents may miss a number of key sedentary activities they engage in throughout the day. Although underestimation may occur for overall time spent sedentary, subjective measurement of screen-based media seems to be relatively consistent with objective measures (3 – 4 hours and 2 – 4 hours per day, respectively).

Objective measurement of sedentary behavior is commonly accepted as valid and reliable; however our findings suggest there are a number of discrepancies between studies. The reasons for the discrepancies in findings are the removal of non-wear time, the exclusion of participants who did not accumulate 600 minutes of register time, no consistent definition of waking hours, and disparities between accelerometer cut-points. Non-wear time is defined as consecutive strings of zero-count epochs lasting 10 or more minutes which are often assumed to be periods of non-compliance (248). However non-wear time may also be viewed as time spent sedentary and, if removed during data analyses, may give inaccurate measurement to time spent in sedentary behavior (249). Objective studies have used different intervals of time to determine non-wear: >10 min of zero counts (207, 216, 250) intervals of >20 minutes of zero counts (204, 206) or intervals of >60 consecutive minutes of zero counts (15, 209, 215, 232). A large number of studies, did not report if non-wear time was removed during data analyses (11, 205, 208, 210, 211, 213, 216-220, 224, 225). It is not uncommon for children to remain in sedentary activity for long periods of time and studies that reported lower levels of sedentary behavior may have misinterpreted sedentary activity for non-wear time. Secondly, a number of studies (212, 213, 216, 218) excluded participants who did not register 600 min of activity per day; the most sedentary participants may well have been excluded from analysis

which could account for the low levels of reported overall sedentary time. Measurement time also varied between studies, with waking hours ranging from 9-15 hours per day or was not stated. This discrepancy means it is difficult to quantify accurately total time spent sedentary in pre-adolescents and makes comparisons between studies difficult. Lastly, the accurate measurement of free-living activity (counts) is essential for research studies in which the measurement of activity is the outcome (112). Objectively measured studies have used a variety of calibration equations (counts vs. energy expenditure) to design accelerometer cut-points that are appropriate for youth (112, 251, 252). ActiGraph cut-points of ≤ 100 counts per min is suggested as the most appropriate level to quantify time youth spend on sedentary activities. Objective studies have either not reported accelerometer cut-points (203, 234), used cut-points below 100 counts per minute (15, 204, 206, 207, 209, 215, 229, 233, 250, 253), below 200 counts per minute (11, 218), below 500 counts per minute (216), below 727 counts per minute (208), below 800 counts per minute (220) or below 1100 counts per minute (205). Applying different cut-points to the same data, changes the estimation of activity and sedentary time (254, 255). As a result several objectively measured studies that are using significantly higher cut-points, may be overestimating time spent in sedentary behavior.

Health outcomes

Studies report children who engage in high levels of sedentary activity, or spend the most time sitting, were at highest risk of being overweight, having higher bodyweight and lower cardio-respiratory fitness (196). Several studies have elected to review associations between bodyweight and screen-based media and reported that bodyweight may substantially influence how much time is spent in screen-based media (144, 182, 193, 256). In particular it was noted that children who spent more than 4 hours per day watching television had the highest skinfold thickness and body weight (196). Furthermore pre-adolescents who reported screen-times of more than 3 hours per day were also 2 to 3 times more likely to have METS (risk factors that occur together and increase the risk for coronary artery disease, stroke, and type 2 diabetes) than those with 1 hour or less. A recently published meta-analysis (12) reports that although a relationship exists between television viewing and bodyweight, it is statistically small. In some instances unaccounted for external factors, such as consumption of energy dense foods, may affect any noted

associations. Consumption of energy dense foods has been positively correlated with time spent engaged in screen-based media (181, 195, 196), but whether it is the consumption of energy dense foods, or time spent sitting that is positively correlated with increased bodyweight, is somewhat unclear. For example, previous studies have reported overweight and obese children will spend more time sitting than normal weight children (15, 24, 139, 160, 161, 163, 172, 190). This suggests that time spent in sedentary activities may increase bodyweight. However, overweight and obese children are reported to consume higher fat and energy foods (257, 258), suggesting that food consumption could confound any association between time spent sedentary and bodyweight. Alternatively, both confounders may work simultaneously as food habits and eating patterns in children are known to be influenced by television advertisements and lack of parental supervision (163, 259).

Apart from bodyweight and food consumption, other physiological health outcomes persist in pre-adolescents who engage in higher levels of sedentary behavior. In particular, pre-adolescents who spend more than 3 hours per day watching television report higher levels of glucose, total cholesterol, triacylglycerol levels, unfavorable waist circumference (132) lower cardio-respiratory fitness (168) and hypertension (244) than pre-adolescents who watch two hours or less per day. Although not all sedentary activities have been linked to psychological difficulties, the effects of time spent in screen-based media activity have been widely researched. Several other studies report that the engagement by pre-adolescents in sedentary activities per se may displace time previously spent with friends or family. Particularly the increase of computer use has contributed to decreased social interaction and increased anti social behavior (188, 246). Some researchers suggest that the internet provides pre-adolescents with an avenue for interaction with peers via social media and ‘chat rooms’, but these relationships are weak and youth are often left with lower self esteem (189).

Interrupting sedentary activities

Given the influence a sedentary lifestyle has on weight gain, consumption of energy dense foods and a number of associated negative health outcomes, the need to reduce or interrupt time spent in sedentary activities in pre-adolescent populations is essential (16). In this review, six intervention studies aimed at reducing sedentary

behaviors in various pre-adolescent populations (16, 159, 166, 200-202), specifically targeting the reduction of time spent in screen-based media activities. It was reported by Robinson (200) that compared with control groups, pre-adolescents undertaking a six month intervention to reduce screen-time had statistically significant decreases in bodyweight, triceps skinfold thickness, waist circumference and waist-to-hip ratio. Gortmaker et al (202) also reported that obesity prevalence was significantly reduced in intervention groups following a two year intervention (and after controlling for baseline covariates). These findings suggest that reducing screen-time (a prominent sedentary activity) has been shown to have considerable positive health implications (260). Although interventions that interrupt sedentary time in children are limited by sample size, a small number of studies (261-264) have shown positive associations, including increased step count, after increasing physical activity in normally sedentary situations (for example, math class). In adults, interrupting sedentary time by standing and walking for example (83), have been shown to be beneficially associated with waist circumference, body mass index, triacylglycerols, and 2 hour plasma glucose (83, 265, 266), after adjustment for sex, age, and race/ethnicity. These findings suggest that increasing physical activity and decreasing or interrupting key sedentary behaviors in pre-adolescent populations should be a key factor in promoting health (164). Potentially, pre-adolescents who engage in long periods of sedentary behavior would most benefit.

Limitations

The fact that the reviewed studies were not quality scored does place limitations on this review. The diverse study methodologies adopted and the disparities between outcome measures, made it impossible to assign a quality score to each study. Study findings were reported, but no further analysis of their quality was undertaken; any quality reporting was obtained from reviewed references. In addition, it is quite possible a number of studies were omitted that may have met the inclusion criteria but were not located through the literature search.

CONCLUSION

In conclusion, it is reported that pre-adolescents spend a large part of their time in sedentary behaviors, with screen-based media activities being the most prominent. Both objective and subjective measures of sedentary behavior show similar findings

of time spent in sedentary activity, but due to the discrepancies between a number of objectively measured studies findings may potentially underestimate time spent sedentary. Nevertheless, this review has highlighted that extended periods of time (3 hours +) spent in sedentary pastime have been associated with negative health outcomes. Prolonged periods of time spent sedentary should be discouraged and future interventions should be focused on decreasing or interrupting time spent sedentary. Particular emphasis should focus on using both objective and subjective methods of measurement.

CHAPTER 3: EFFECT OF INTERMITTENT SITTING ON ACUTE POSTPRANDIAL LIPEMIA IN CHILDREN: A FEASIBILITY STUDY

This chapter comprises the following paper which will be submitted to the Journal of Physical Activity and Health. “Effect of intermittent sitting time on acute postprandial lipemia in children”.

ABSTRACT

Introduction: Sedentary behavior in children has been associated with unhealthy dietary intake, and obesity in adulthood. While interrupting sitting time has been shown to improve metabolic health in adults, to date similar studies on metabolic risk factors in children have not been conducted.

Purpose: The aim of this study was to investigate the effect of interrupting sitting time on acute postprandial plasma TAG in healthy pre-adolescent children following four high fat meals.

Methods: Twelve pre-adolescent children underwent two 8.5-hour testing sessions separated by 7 days. On day 1 participants interrupted sitting with moderate intensity physical activity every 30 minutes. On day 2 participants remained sedentary. Four meals high in fat (breakfast, 90 g; morning tea, lunch and afternoon tea, 40 g respectively) were consumed to simulate daily eating patterns in pre-adolescent. Blood tests were taken every second hour from 08.30 to 16.00, to measure TAG, glucose, and cholesterol levels.

Results: Overall, total area under the concentration-time curve for all measures was compared between day 1 and day 2 and calculated using paired t-tests. Data was log transformed at each test (baseline, two, four, six and seven hours from baseline) to provide a % change in mean using a modified Cohen’s effects scale. The combined responses showed higher levels of TAG on day 1 than day 2: the difference was -3.2%; (90% confidence limits ($\pm 36.5\%$)) but the effect was unclear. Individual TAG data was reviewed, TAG levels were higher on day 2 compared to day 1 in eight participants with a very large mean change of 35.1% ($\pm 15.7\%$). The results two, four and six hours after baseline for the eight participants showed a likely change for TAG mean concentrations for day 2 compared to day 1 of 21.6% ($\pm 15.6\%$); 48.7% ($\pm 38.8\%$) and 56.5% ($\pm 75.1\%$) respectively. All findings were standardized with total meal fat consumption and baseline data to ensure compliance. The protocol of

interrupting sitting time with moderate-high intensity activities and frequent blood sampling was feasible with this group of pre-adolescents.

Conclusion: Results showed a trend towards the enhancement of postprandial clearance in some pre-adolescents but not others. Future studies with larger sample sizes are necessary for more convincing outcomes.

INTRODUCTION

The independent effects of sedentary behavior may influence the development of lifestyle disease in pre-adolescents as they move into adulthood (267). Key sedentary activities, such as television viewing, passive transport, reading, working on the computer or forms of socialisation have an increasing effect on lifestyle disease (1-4) independent of whether individuals meet daily physical activity guidelines (5).

In recent years, measurement of sedentary behavior has gained attention in relation to overweight and obesity in children (268). In order to understand the impact sedentary behavior has on negative health outcomes, Hamilton, Hamilton, & Zderic (22) suggested that it is important to study sedentary behavior separately from physical activity. Sedentary behavior, or sitting for comparatively long periods of time, causes the loss of opportunity for cumulative energy expenditure, or otherwise known as non-physical activity activity thermo genesis (NEAT), which can cause a loss of thousands of small muscular contractions over the course of a day (22).

Time spent sitting has been linked to lipoprotein lipase (LPL) activity in animal models. LPL is an enzyme that binds to circulating lipoprotein derived fatty acids (chylomicrons) in the blood stream and has a central role in determining metabolic syndrome. Recent evidence (269) showed that elevated levels of chylomicrons were associated with cardiovascular risk factors such as dyslipidemia in children. Impaired LPL activity may also contribute to the risks frequently observed during metabolic diseases such as obesity, type 2 diabetes and cardiovascular disease (31). Animal models have shown that LPL activity (31, 270) is suppressed during prolonged sedentary behaviors limiting the absorption of chylomicrons (31). In healthy adults (40) significant increases in plasma triacylglycerols and decreases in HDL cholesterol have been noted with an 18% decrease in LPL activity after 11 days of bed rest .

It has been suggested that impairment of LPL after a meal leads to postprandial lipemia, the inability to rapidly clear chylomicron particles following lipid dietary intake. Consequently, sustained increased levels of LDL, cholesterol and triacylglycerols (TAG) can lead to atherosclerosis, cardiovascular disease and obesity in the adult population (271).

Studies in adults (47, 272-275), adolescents (36, 51, 52) and children (53, 55) have measured the postprandial response from prior physical activity and/or intermittent games on postprandial clearance and observed decreases in TAG concentrations. None of the studies however, determined the acute effect of interrupted sitting on TAG concentrations. The purpose of this study was to compare TAG response in healthy pre-adolescents following a high fat diet during prolonged and interrupted sitting. Pre-adolescents were chosen as participants because emerging evidence suggests that chylomicrons following a meal, play a role in the onset and development of cardiovascular risk factors in children which increase with age (269).

METHODS

Participants

Twelve healthy pre-adolescents, 8 girls and 4 boys, aged 12 ± 2 years (mean \pm SD) were recruited for this study, from primary schools within the Auckland region, New Zealand. A summary of all participant characteristics is shown in Table 3.1. Participants were excluded if they engaged in high levels of extracurricular physical activity, had a prior medical condition, were taking any medications or had a current condition that would limit physical activity participation.

Preliminary measures

Prior to participation, participants and their parents were informed of the nature and risks of the study. Written informed consent and assent was obtained preceding participation. Ethical approval for the study was granted by the Auckland University of Technology's (AUT) ethics committee. Anthropometric measurements were taken two weeks prior to study commencement. Using a portable stadiometer (Seca 214, UK) and electronic scale (Seca 813, UK), measurements were taken to the nearest 1mm or 1g. Measurements were then repeated on the first testing session, to ensure

accuracy. Height (cm) and weight (kg) measurements were used to calculate body mass index (60). Physical activity status was measured two weeks prior to participation to gauge daily level of physical activity and inactivity for each participant. Activity measurements were collected through ActivPAL accelerometry. Accelerometers were worn for a total of 4 days (before visiting the laboratory) to measure activity, inactivity and exercise intensity. Valid data included two weekdays and one weekend day. Recorded activity and inactivity and exercise intensity is shown in Table 3.1.

Table 3.1. Descriptive participant characteristics (mean \pm SD) (n=12)

Measure	Mean	\pmSD
Age (y)	12	2
Body Mass (kg)	49	10
Height (cm)	153	11
BMI (kg.m⁻²)	21	2
BMI z score	1.56	0.6
% Time spent sitting* (h)	84	6
% Time spent standing (h)	11	4
% Time spent stepping (h)	5	3
Step count	76	21
Sit to stand transitions (counts)	8	24
EE (METS.h)**	9	15

*Includes sleeping hours

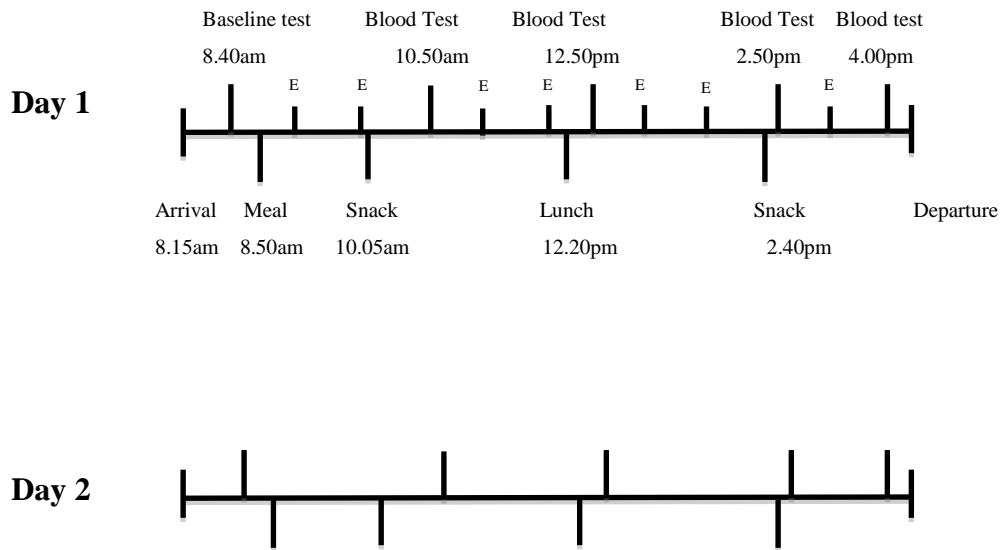
** METS per hour

Experimental design and procedures

All participants were required to attend two testing sessions (08:00-16:15) at the AUT Human Performance Laboratory following a 12 hour fast. Testing was completed between September and October 2010. Each testing session was separated by a period of seven days. On arrival, height and weight was re-measured and participants were asked to wear an ActivPAL accelerometer which would track their activity levels for the course of the day. On day 1 participants engaged in their

choice of sedentary activities (television viewing, computer games, reading, and drawing). All participants completed four minutes of intermittent activity (197 ± 51 steps) every thirty minutes on day 1 starting from 09:25. The number of steps taken and physical activity intensity were recorded continuously as well as time spent sitting throughout the intermittent physical activity bout using the ActivPAL accelerometers which then provided cadence (step intensity and duration) levels. All participants were encouraged to participate at a moderate level of activity which was determined visually by participant respiration. Participants engaged in child-friendly activities including; soccer, basketball, obstacle courses, stair climbing, dancing, aerobics, frisbee, cart wheel races and touch rugby.

At 2 hour intervals a 500 μ l blood sample was taken using paediatric lancets to measure TAG and glucose levels. After consultation with paediatric nurses and phlebotomists, blood withdrawal was first demonstrated to participants on a life-size doll. This allowed the researcher to gauge the reactions of each participant and to ask the participants how the 'doll' might be feeling, and from those responses devise strategies with each participant to ensure comfort during blood sampling. All research assistants were trained in administering finger pricks on pre-adolescents and were overseen by a registered nurse. On day 2 participants were again re-fitted with ActivPAL accelerometers on arrival and were wheelchair bound, being assisted to the bathroom when required. Participants remained in their choice of sedentary activities the entire day. Measurements were repeated at the exact times. See Figure 3.1 for a schematic representation of the study design.



E= Intermittent Activity

Figure 3.1. Schematic representation of the testing period on day 1 and day 2

Dietary intake

On day 1 and day 2, participants were provided with an identical baseline meal that consisted of a McDonald's double quarter pounder with cheese, medium fries, McDonald's hashbrown and full fat chocolate milk drink. The meal was consumed between 8.40am-8.55am, directly after baseline testing. The baseline meal was high in fat with a macronutrient composition of 90g fat, 140g carbohydrate and 77g protein (29.3% fat 45.6% carbohydrate 25.1% protein). Water was consumed ad libitum. Participants also consumed three smaller meals throughout each testing day; morning tea, lunch and afternoon tea. The three smaller meals were designed to approximate the unhealthy eating habits of some children and included high fat options such as: 1 cheese and bacon croissant, 200g chocolate or goody gum drops ice-cream, 1 cream doughnut and 2 milk-based drinks. Participants were also offered a variety of fruit, however this was not consumed. Participants stopped eating when full and the remaining food was weighed. At completion of the testing session, parents were advised to provide a meal for dinner containing vegetables and/or fruit. Macronutrients and micronutrients of food consumption was analysed using FoodWorks® Premium. FoodWorks® Premium is an Australian and New Zealand software program for nutrient analysis.

Blood analysis

Blood samples were collected using OSHA high flow pediatric lancets (BD Microtainer®, BD Australia) and were drawn into sterile heparin tubes (BD Microtainer®, BD Australia) purchased from BD vacutainer. Prior to collection participants were offered the opportunity to use a local anaesthetic containing lignocaine and prilocaine (Emla, AstraZeneca Limited, NZ) and could move to a position in which they felt comfortable. Skin was warmed before each puncture to increase blood flow and the testing room was heated to 22° C prior to participant arrival. Warm water at a temperature no higher than 42° C was used to cover the site for three to five minutes. This technique increased blood flow to the site up to sevenfold, does not burn the skin, and does not result in significant changes for routinely tested analytes. The puncture site was thoroughly cleansed with 70% isopropanol. Skin was air-dried. The finger puncture was performed using a sterile, OSHA approved blood lancet creating a deep puncture (1.5 mm) at the chosen site. The initial drop was discarded and 0.3-0.5ml of blood was collected for analysis and then centrifuged at a recommended speed of 5000 rpm (revolutions per minute) for 5 minutes. Plasma was separated from the red blood cells immediately after centrifugation and aliquoted into a sterile micro tube. Plasma was immediately frozen and remained in a -80c freezer until analysed.

Lipid (cholesterol, TAG, high density lipoprotein (HDL) and low density lipoprotein (LDL) analysis was performed at Labplus Auckland City Mission hospital. Samples were sent to an accredited ISO15184 lab for analysis using the ROCHE automated modular analytical systems. All tests were performed with high quality assurance as per the contract with the laboratory. Principles of the tests were based on colorimetric assay and results were returned by mail.

Statistical analysis

All descriptive statistics were presented as means and standard deviations (SD). Independent variables included age, bodyweight and sitting time. The dependent variables were the blood parameters glucose, cholesterol and TAG. Area under the concentration-time curve was calculated for all variables between day 1 and day 2 at each test and was compared using paired t-tests. Participant data was adjusted for

weight and height using Hopkins spreadsheets. Raw data were log transformed and presented as the mean value and standard deviation over the period of observation. The back transformed between subject standard deviation was used to convert the observed changes into standardized (Cohen) changes in the mean. The smallest standardized change was assumed to be 0.20 (276). The value of 0.20 gives chances that the true effect is at least small. To make inferences about true (population) values, the uncertainty in the effect was expressed as 90% confidence limits and as likelihoods that the true value of the effect represents substantial change (negative or positive) (92). If the likely range overlapped substantially positive and negative values, we inferred that the outcome was unclear. The chances were estimated using the same assumptions about the outcome statistic as when estimating p values or confidence intervals. The descriptors used were: <1%, almost certainly not; 1-5%, very unlikely; 5-25%, unlikely or probably not; 25-75%, possibly or may be; 75-95%, likely or probably; 95-99%, very likely; >99%, almost certainly. Further comparisons were made between each test on day 1 and day 2 at baseline, two hours, four hours, six hours and seven hours. Data are presented as mean (%), change in mean (%) between day 2 and day 1 with the relevant SD (%). The uncertainty in the mean change is described qualitatively.

RESULTS

Baseline meal comparisons between day 1 and day 2 showed a change of -4.6% \pm 5.6% in the level of fat consumed. The difference in the baseline meal was trivial. Accelerometry data confirmed participants remained entirely sedentary between 08:00 to 16.30 on day 2.

Differences in TAG, glucose and cholesterol concentrations between day 1 and day 2 for all participants (n=12) were calculated as mean area under the concentration-time curve and are shown in Table 3.2. No significant differences between day 1 and day 2 were noted in glucose, however total cholesterol difference may be possibly beneficial. Cholesterol and glucose values fall in the normal range.

Table 3.2. Overall percent mean and SD and percent difference in the mean were calculated as mean area under the concentration-time curve between day 2 and day 1 with a qualitative outcome descriptor. Data were adjusted for BMI and fat intake.

Measurement*		Mean (%)	SD (%)	%Δmean (day 2-day 1)	CL	Outcome
Triacylglycerols** (mmol/L)	day 1	82.4	31.7			
	day 2	46.6	28.5	-3.2	±36.5	Unclear
Glucose** (mmol/L)	day 1	193.2	9.6			
	day 2	196.4	18.7	-3.2	±9.9	Unclear
Total Cholesterol** (mmol/L)	day 1	153.9	22.1			
	day 2	147.0	22.5	7.2	±9.8	Possibly

day 1, intermittent activity; day 2, sitting; CL, confidence limit, %Δmean; percentage change of mean

*excluding T1

**Log transformed data

TAG concentrations

Plasma total TAG concentrations (mmol/L) over the course of the day for all participants (n=12) are presented in Figure 3.2. Data were analysed using area under the concentration-time curve.

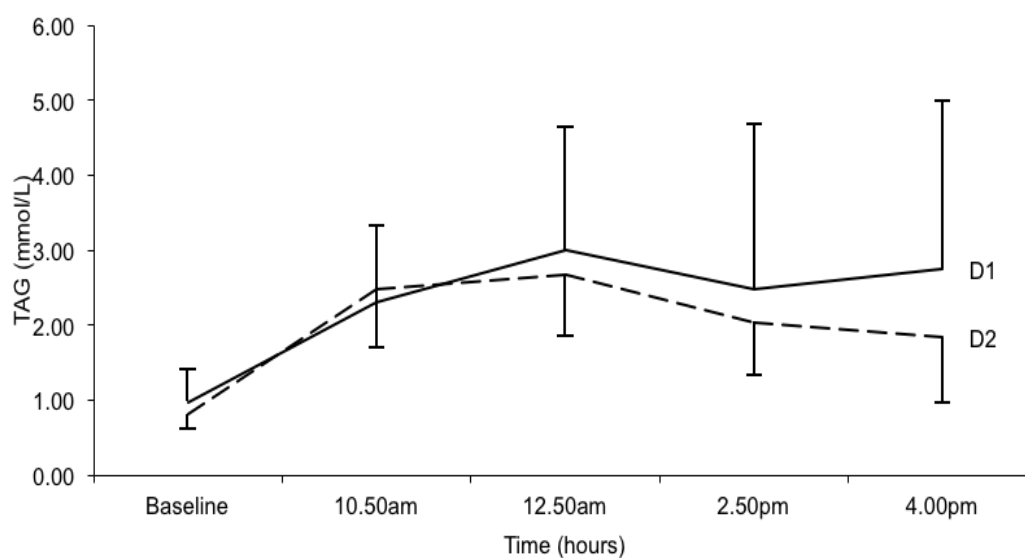


Figure 3.2. Mean \pm SD plasma total TAG concentrations in the fasted state and over the next 8 hours after ingestion of three high fat meals on day 1 (D1) (intermittent) and day 2 (D2) (sitting). Area under the concentration-time curve comparison of day 1 and day 2 is unclear.

TAG mean concentrations for all participants (n=12) at specified times during the day, SD, the mean difference between day 1 and day 2 and 90% confidence limits with a qualitative descriptor of the uncertainty in the change scores are presented in Table 3.3.

Table 3.3. Overall TAG results for day 1 and day 2 for all tests. Mean \pm SD and change in mean are presented as percents

Measurement		Mean (%)	SD (%)	% Δ mean (day 2-day 1)	\pm CL	Outcome
Test 1 ^a	day 1	-11	39			
	day 2	-24	27	-13	± 28	Possibly
Test 2 ^b	day 1	75	41			
	day 2	86	31	12	± 26	Possibly
Test 3 ^c	day 1	99	46			
	day 2	94	33	-4	± 48	Possibly
Test 4 ^d	day 1	69	62			
	day 2	66	38	-11	± 69	Possibly
Test 5 ^e	day 1	83	56			
	day 2	50	46	-22	± 51	Possibly

day 1, intermittent activity; day 2, sitting; \pm CL, confidence limit, % Δ mean; percentage change of mean

^a=Test 1, baseline; ^b=Test 2, 2 hours from baseline; ^c=Test 3, 4 hours from baseline; ^d=Test 4, 6 hours from baseline; ^e=Test 5, 7 hours from baseline

*log transformed data

Individual response data shows that TAG levels were higher on day 2 compared to day 1 in eight of the participants (2, 4, 5, 6, 8, 9, 10, 11) (Figure 3.3). Data highlighted consistently increased TAG concentrations on day 2 at two, four and six hours after baseline compared with day 1.

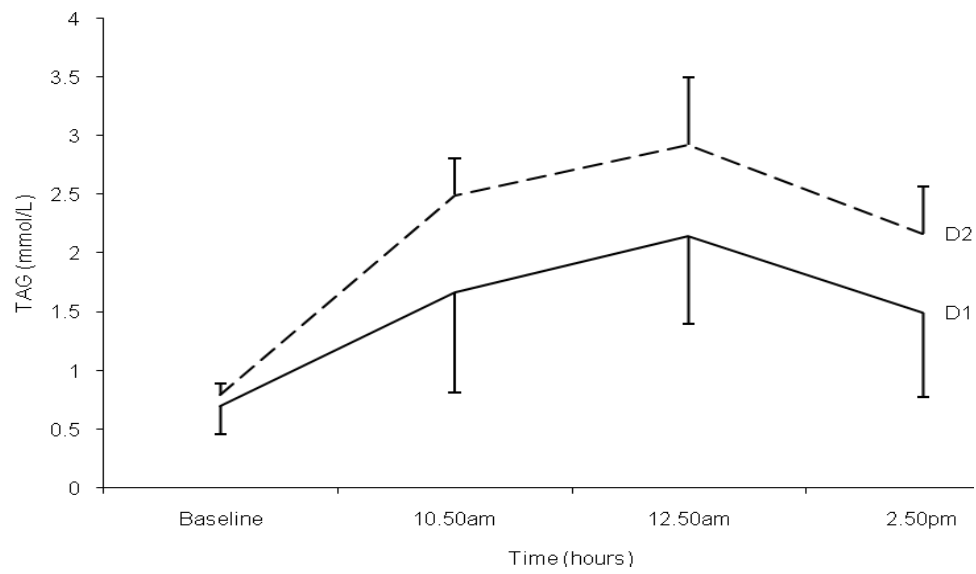


Figure 3.3. TAG results for day 1 (D1) and day 2 (D2) in eight participants, raw data excluding T5

Mean TAG concentrations (%) for the eight participants at specified times during the day, SD, the mean difference between day 1 and day 2 and 90% confidence limits with a qualitative descriptor of the uncertainty in the change scores are presented in Table 3.4.

Table 3.4. TAG results for day 1 and day 2 in eight participants. Overall means, SD and difference in the mean (with a qualitative outcome descriptor) between day 1 and day 2 are presented as percents

Measurement		Mean (%)	SD (%)	%Δmean (day 2-day 1)	±CL	Outcome
Test 1 ^a	day 1	-36	13			
	day 2	-27	34	9	±43	Unclear
Test 2 ^b	day 1	50	18			
	day 2	86	35	22	±16	Very Likely
Test 3 ^c	day 1	73	28			
	day 2	105	25	49	±39	Very Likely
Test 4 ^d	day 1	37	29			
	day 2	72	37	57	±75	Likely
Test 5 ^e	day 1	59	29			
	day 2	65	44	17	±54	Possibly

day 1, intermittent activity; day 2, sitting; ±CL, confidence limit, %Δmean; percentage change of mean

^a=Test 1, baseline; ^b=Test 2, 2 hours from baseline; ^c=Test 3, 4 hours from baseline; ^d=Test 4, 6 hours from baseline; ^e=Test 5, 7 hours from baseline

Raw data from the remaining four participants are represented in Figure 3.4. Data highlighted increased TAG on day 1 at two, four and six hours after baseline compared to day 2.

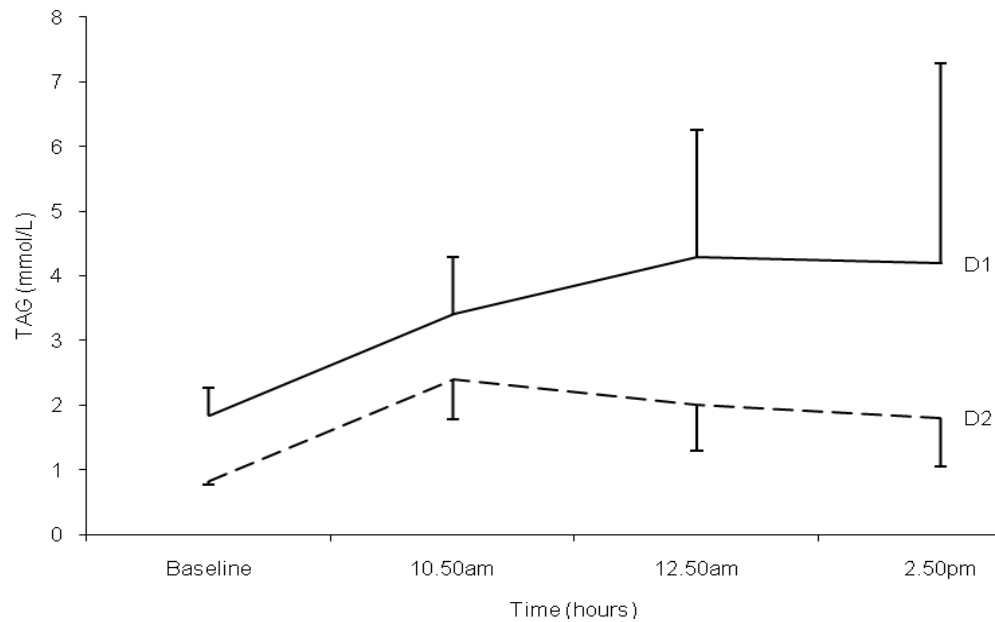


Figure 3.4. TAG results for day 1 (D1) and day 2 (D2) in four participants, raw data excluding T5

DISCUSSION

This is the first study to investigate the metabolic effects of interrupting sitting time in healthy pre-adolescents under 15y in relation to TAG clearance following a high fat diet. The main finding from this study was that when sitting was interrupted by short bouts of moderate intensity physical activity there was a clear reduction in TAG concentrations in eight out of 12 participants. Postprandial clearance was observed as early as two hours with intermittent sitting compared to continuous sitting. The clearance was maintained for the next six hours. When studies with adolescents (36, 51, 84) and adults (42, 47, 273-275, 277-279) investigated the effect of acute physical activity or intermittent physical activity (performed on the same day) on postprandial response it was found that activity increased postprandial clearance. A possible mechanism for the enhanced TAG clearance with physical activity in the eight participants is through the stimulation of LPL activity. Physical activity is known to lead to an increase in muscle LPL activity, and increased skeletal blood flow during physical activity can enhance TAG clearance (42). However, because of the small sample size, it is possible that the increased TAG clearance on day 1 might be due to type 1 error that is a false positive. Nevertheless the results showed a trend towards the expected directions for eight of the 12 participants.

Four participants exhibited delayed postprandial clearance when sitting was interrupted with moderate intensity physical activity. This finding is similar to the work conducted in adults (274, 275) who performed 30-45 min uninterrupted physical activity bouts prior to a high fat meal on the same day. A possible reason for a delayed postprandial clearance in this group is that TAG-rich lipoproteins are not thought to be an important substrate for muscle metabolism during moderate to vigorous physical activity (280). However, because of the small sample size, it is possible that the decrease in TAG clearance on day 1 might be due to type 2 error that is a false negative. In addition, it was also noted that there were slight differences at baseline between the two groups, however further analysis showed the difference was unclear.

Most postprandial research is carried out after an overnight fast (281) and after the consumption of a high fat meal, TAG will typically peak at 180 min. Studies in

adolescents noted TAG peaks at 120 min (36), 180 min (51, 52), 240 min (53) and in adults (42, 47) TAG levels predominantly peaked much later. In this study, TAG peaked at 240 min after the consumption of the baseline meal on both day 1 and day 2 in all participants.

There is a possibility that intermittent physical activity may reduce cholesterol levels, as found in previous adolescent research (44, 52, 84). Cholesterol concentration is considered a marker for the efficiency of TAG metabolism in the postprandial state (282). Potentially during a postprandial state the risk of cardiovascular disease is increased and HDL and LDL cholesterol particles are converted into potentially atherogenic agents.

In this study, there was little difference between the glucose levels on day 1 and day 2. This finding appears to be consistent with studies of a similar research design (43, 44, 51, 52, 283). However there are others that have reported small changes (283). Although limited evidence exists as to why reported glucose change is unclear between testing days, it is thought that the blood tests may not have occurred regularly enough to detect glucose peaks after meal consumption.

There were limitations to the present study. Intermittent physical activity was not standardised and participants were not randomized during testing. Differences in the level of sexual maturation within the participants were also not recorded and may have had an impact on the results. As McEnaney et al (36) contend, there is little research investigating the impact of maturation on postprandial response and no relation has been previously reported (51, 52, 54). Due to ethical considerations, pre-adolescents were not coerced to finish each meal but allowed to stop eating when they felt full. All unconsumed food was appropriately standardized. Nevertheless, the study was designed to replicate 'real life' unhealthy food consumption habits, and pre-adolescents consumed food throughout the day. Typically, in postprandial lipemic research, only one meal is consumed.

In conclusion, the results suggest that postprandial clearance is enhanced in some pre-adolescents after two hours of intermittent physical activity but not others. However, these results should be viewed with caution as further research will need to

be conducted on a larger sample to confirm findings. The results may provide initial evidence into the metabolic effects of sedentary behavior in pre-adolescents. Interrupting sedentary activities may be key to improving health in pre-adolescents.

CHAPTER 4: DISCUSSION

Pre-adolescents aged 8-15years spend a large proportion of their day engaging in various sedentary activities (15, 205, 215, 221). Evidence suggests that sitting is a contributing factor to the increase and prevalence of childhood obesity (210) and associated negative health outcomes. Therefore, decreasing or interrupting the amount of time pre-adolescents spend in sedentary activities, should be considered a priority in future physical activity-related public health recommendations. The aims of this thesis were: 1) to critically review the objective and subjective measures of time spent in sedentary behavior in pre-adolescent pre-adolescents and to report the associations between time spent in sedentary activity and health outcomes, 2) to investigate the effect of intermittent activity on postprandial TAG clearance and 3) to discuss the feasibility of the methods used in measuring postprandial lipemia in pre-adolescents.

The following section explores the findings of the literature review and results, and will discuss the feasibility of the methods used to measure postprandial lipemia in pre-adolescents. The findings will be discussed in terms of their implications and application to public health. Strengths and limitations will be discussed followed by areas for future research and conclusions.

CONTEXT

Measurement of sedentary behavior

The literature review provided a critical review of the measurement of time pre-adolescents spent in sedentary behavior and emphasised the associations between overall time spent sedentary and potential negative health outcomes. Although the review highlighted a proliferation of research, it is the first review to quantify the measurement of time spent in sedentary behavior. Time spent in sedentary activity has been engineered into people's lives across many settings, including transportation, the workplace, schools and homes (62).

Measurement of sedentary behavior is complex, and consequently periods spent being sedentary is both over- and underestimated. In particular, subjective measures of sedentary behavior focus on the measurement of certain sedentary activities rather

than encompassing a measurement of overall time spent in a sedentary state. This created a number of complications when comparing studies that variously utilized subjective and objective methods. Regardless findings emphasised that spending extended amounts of time in sedentary activity, irrespective of type or duration, will likely result in a number of negative health outcomes, for example overall time spent sitting in pre-adolescents was associated with adult weight gain (174, 236). The findings provide a valid reason to decrease or interrupt time spent being sedentary.

While a decrease in overall time spent in sedentary behavior is recommended, several studies in adults and adolescents have shown corresponding health benefits when sitting time is interrupted. The first study to examine interrupted sedentary behavior found that the enforced breaks were beneficially associated with a number of cardiovascular and metabolic variables (83). This finding is supported by sedentary behavior recommendations, which encourage youth to decrease time spent in sedentary pursuits. This thesis aimed to investigate if interrupting sedentary activity decreases noted health risk factors by measuring postprandial clearance. To date, no published studies have reported the benefits of interrupting sedentary time in pre-adolescents, so we believe that this study is novel and will contribute to the growing body of knowledge on the benefits of interrupting sedentary time.

SIGNIFICANCE OF THE FINDINGS

Lifestyle disease in pre-adolescent children

Lifestyle related diseases, such as obesity and type 2 diabetes are now being noted in pre-adolescents (37). It is well-known that many lifestyle disease risk factors are caused by over consumption of energy dense foods and lack of physical activity (77). Only recently has sedentary behavior been defined as a unique activity, with time spent sitting explained as a loss of opportunity for cumulative energy expenditure. As the previous paragraphs highlighted, time spent in sedentary activity has been linked to a number of negative health outcomes in youth and also plays a role in disease manifestation. A number of these outcomes, such as weight gain, are risk factors for lifestyle related diseases. Therefore, it is reasonable to assume that the combination of energy dense food consumption, low physical activity levels and time spent sitting will impact the risks of lifestyle related disease in youth.

A number of lifestyle disease risk factors such as obesity and cardiovascular disease, have been linked to elevated levels of TAG in adults. Elevated levels of TAG will occur after the consumption of a high fat meal. TAG levels will then naturally return to a fasting state within three to four hours. However, poor clearance of TAG (postprandial lipemia) is considered an early predictor of lifestyle disease. In particular, the secretion of TAG lipids are up-regulated in obese adults, or those with insulin resistance (284). It is unknown if elevated TAG levels are associated with lifestyle disease in pre-adolescents. But evidence confirms that a number of risk factors including dyslipidemia, endothelial dysfunction, high blood pressure and insulin resistance are correlated with obesity and the progression of cardiovascular disease in pre-adolescents (29). Dyslipidemia is characterised by abnormality of lipids in the blood, and is usually associated with elevated levels of cholesterol and triacylglycerols. Dyslipidemia is considered a key feature of metabolic syndrome and has been noted in overweight pre-adolescents. Along with other risk factors such as smoking and hypertension, dyslipidemia can cause atherosclerosis, or accumulation of plaques within arteries. This, in turn, can predispose pre-adolescents to coronary artery disease and peripheral artery disease, leading to myocardial infarction, stroke, and other serious health issues later in life. Because there is a strong correlation between adult obesity and lifestyle disease, it would suggest childhood obesity is also associated with lifestyle disease risks. In addition, evidence suggests that childhood obesity predicts adulthood obesity (285-287) and obesity has been associated with time spent sitting.

Intermittent activity and postprandial clearance

Physiological interpretation

The main finding from our study was that when sedentary behavior was interrupted by short bouts of moderate intensity physical activity there was a clear reduction in TAG concentrations in eight out of 12 participants. This finding suggests that moderate intensity activity increased postprandial lipemic clearance as previously demonstrated in adult and adolescent studies (42-45).

Although the majority of TAG regulation occurs in the adipose tissue, there is evidence that skeletal muscle plays a role in LPL activity (288). Insulin stimulates

adipose tissue LPL, while down-regulating muscle LPL (289). LPL activity in adipose tissue is not achieved until after three to four hours of insulin stimulation and therefore a TAG peak will occur four or five hours after consumption (42, 290, 291). The effect of postprandial lipemic uptake in our study peaked at 4.5 hours after baseline consumption. However, previous postprandial research with pre-adolescents suggested that TAG uptake occurred between three or four hours after eating (41). Although it is difficult to explain the later peak, it might be worth noting that the pre-adolescents in previous studies were younger and TAG may be absorbed differently. Furthermore, in our study blood testing was completed every second hour; if blood had been taken every hour we may have been able to more closely monitor any variations.

After a peak of TAG concentration during the early afternoon, TAG levels decreased, despite the consumption of an additional two meals containing 40 g of fat. One of the reasons that TAG levels did not continue to peak throughout the day is that previous insulin stimulation affected subsequent insulin-stimulated processes in additional meals which reinforce the pattern of TAG storage in adipose tissue. Therefore, when the three meals were consumed during the day, adipose tissue LPL activity was the highest in the late afternoon (292).

It is also possible that acute physical activity decreases postprandial insulin (288). As explained earlier, insulin stimulates adipose tissue LPL, but acute physical activity induces a progressive up-regulation of muscle LPL and a temporal increase in muscle blood flow (293). Therefore increased skeletal movement leads to an increase in muscle blood flow, which is a common response to increased muscle activity. Increased muscle blood flow during physical activity is considered to enhance TAG uptake by increasing the exposure of LPL to TAG lipoproteins. Muscle blood flow remains high for a short time (30 mins) after activity (294, 295). Although we had no way of measuring this, potentially TAG uptake into muscle during periods of intermittent activity was higher because of increased exposure of LPL. In contrast, however, participants who overly exerted themselves during the intermittent activity may have rapidly increased muscle blood flow. Blood that moves too rapidly can limit TAG exposure to LPL. If TAG were not being exposed to LPL the postprandial lipemic response would be increased and a decrease in the level of TAG would only

be noted later in the day. Although this is a plausible reason as to why higher levels of TAG are found in some participants, it does not explain why higher levels of TAG on day 1 were found in four of our participants.

In addition to muscle metabolism there are a variety of reasons TAG levels may have been higher in four of our participants. These include: genetic conditions such as familial dyslipidemic hypertension, visceral obesity, lipoprotein lipase deficiency, family history of premature cardiovascular disease and the rate of digestion and intestinal absorption of the meal. It is worth noting that no participants reported family history of lifestyle disease and that three of the four participants had a sibling (including a twin) participating in the study who did not exhibit higher levels of TAG on day 1. In addition, none of the pre-adolescents were overweight or obese. Perhaps two further theories that are worth exploring: 1) it may be that these participants simply ate more high fat food on day 1 or; 2) that these participants started with higher levels of TAG which may have remained higher throughout the day. However, after comparing individual responses, two participants who had higher levels of TAG on day 1, consumed more food on day 1 than day 2; the other two consumed less. After standardizing for any effect, the difference in consumption was trivial for all four participants, which suggests that the difference was irrespective of high TAG levels on day 1. Differences in the baseline level of TAG were also analyzed between day 1 and day 2. After analysis, the magnitude of results was unclear and suggested trivial differences.

Statistical interpretation

In this study, more participants noted a decrease of TAG on day 1 so we confirmed our hypothesis as correct even though overall mean between each testing day was unclear. However, because of the small sample size, increased TAG clearance in these participants may draw a type 1 error, that is a false positive. A type 1 error occurs when the alternate hypothesis is incorrectly rejected. In addition, based on the fact that four participants had an increase of TAG on day 1, potentially we may have also drawn a type 2 error. A type 2 error, also known as a false negative, occurs when the null hypothesis (intermittent sitting will not enhance postprandial clearance) fails to be rejected. These outcomes further reinforce that a larger sample size is required.

FEASIBILITY AND IMPROVEMENT OF THE METHODS

The third outcome for this thesis was to discuss the feasibility of the methods used to measure postprandial lipemia in pre-adolescents. Although a number of studies have previously measured postprandial lipemic responses in pre-adolescents after physical activity, this was the first study to use postprandial response to measure the effect of intermittent sitting.

Participants

Pre-adolescents aged between 8-15 years are considered pre-adolescents as emphasized in Figure 4.1. However the physical development of pre-adolescents in this age category varies significantly. Pre-adolescent participants in this study were 12 ± 2 years of age. Although age did not vary substantially, observed physical maturity was diverse. It is recommended that for future studies pre-adolescents are recruited based on Tanner stages. Tanner stage defines physical measurements of development based on external primary and secondary sex characteristics, such as the size of the breasts, genitalia, and development of pubic hair (296, 297). Although there is little research investigating the impact of maturation on postprandial response and no relation has been previously reported (36, 51, 52, 54), it is believed that pubertal testosterone increases may escalate fat metabolism (298) and potentially confound results.

Methodology

Activities

Strengths of the testing procedure included that all participants enjoyed participating in the sedentary and intermittent activities during each testing day. Based on researcher observations, the most preferred activities were screen-based media. Although this study provided a range of sedentary activities for participants to engage in, many were not utilized. Based on the findings from the literature review and this study it would be feasible to offer only screen-based media in future similar studies.

In this study intermittent activity undertaken on day 1 was not standardized between each 4 minute bout. Although intermittent activity was similar in all participants, as measured through accelerometry it was not exactly the same between days, or

between participants, and is a noted limitation in the section below. The advantage of standardizing intermittent activity is that it can reduce measurement error. One way of standardizing intermittent activity in a future study would be to use treadmills on set speeds. Using different treadmill speeds may, to a degree, replicate the daily walking and running movements of pre-adolescent pre-adolescents. All activity can be easily monitored and recorded for other participants to replicate. If such a study was undertaken, a number of treadmills will be required, or pre-adolescents will need to come in on different testing days.

Blood withdrawal and collection

Blood withdrawal was also a major concern in this study for both the parents and participants. Participants physically and verbally expressed their disenjoyment of the blood sampling during the testing, and when returning the following week. After each sample was taken the participant was asked to report their level of enjoyment, which was recorded on a collection sheet (Appendix E). The majority of participants reporting that they disliked the finger prick. Surprisingly, however, no participants refused to undertake a finger prick. Any participants who were nervous or uneasy, were supported by a sibling or parent. Although no refusal occurred, it is recommended that future studies employ substantial humour-based distraction techniques, such as funny movies, music and pictures to assist with calming a nervous participant. In addition, all participants should be given the option of using finger numbing cream one hour prior to the finger prick.

During this study blood was collected for analysis and then centrifuged at the recommended speed of 5000 rpm (revolutions per minute) for five minutes, in accordance with appliance guidelines. However, on occasion blood remained coagulated and did not separate after centrifugation. A likely reason is that the blood underwent haemolysis crisis (299). This may occur when red blood cells are destroyed from over-squeezing blood from the finger. It is recommended that if haemolysis is suspected, blood is centrifuged for a minimum of eight minutes to reduce haemolysis.

Diet

Participants responded positively to the selected diet. Although some reported difficulty in consuming each meal, participants reported the diet was 'tasty'. A strength of this study was that participants were offered recognisable and branded foods. Similar studies in adolescent and adult populations have opted for alternative homemade food choices, including high fat milkshakes, muffins and cereal mixes. No studies reported if the dietary options were feasible or enjoyed. In future studies, we believe that it could be possible to reduce the overall fat content consumed in the three meals following the baseline meal (morning tea, lunch and afternoon tea), and still maintain the expected postprandial response. Postprandial lipemia research suggests that additional meals will be more readily absorbed as insulin regulation is working at an optimum rate. Nevertheless, it is important that meals still contain on average at least 20 grams of fat so the expected postprandial response is not affected. Ideally, meals that have a lower fat content should also include a number of healthy alternatives such as fruit or vegetables, which will ensure participants meet the daily National Food and Nutrition Guidelines.

Timing of events

In this study, the timing of events was crucial. Day 1 was structured around the intermittent activity occurring every thirty minutes and blood withdrawal occurring every second hour. To a degree, meal timing was flexible so consumption occurred at 8.40am, 10.05am 12.24pm and 2.40pm respectively. Day 2 replicated day 1, however the intermittent activity was removed.

There were a number of difficulties encountered with event timing that were not expected. For example, participants were allocated 10 minutes to consume each meal; however some participants naturally ate much slower and could not finish within 10 minutes. It is likely, the heavy calorie load may have also decreased consumption speed as participants got fuller faster. Another difficulty in consuming the meal was that on occasion meal consumption was placed directly after an intermittent activity bout. When participants returned from their intermittent activity they were required to immediately start consuming a meal. It is suggested that future studies offer at least 20 minutes for consumption of each meal and in addition offer a

10 minute recovery period after each intermittent activity bout prior to any meal consumption.

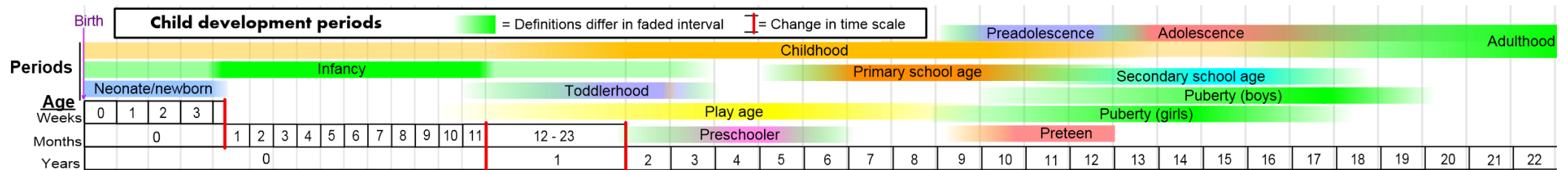


Figure 4.1. Child development periods (Häggström, M., 2009)

STRENGTHS AND LIMITATIONS

In light of the findings, there were some strengths and limitations to the research that should be considered.

Firstly, there was initial difficulty recruiting participants through schools. The main obstacles included difficulty contacting schools, low agreement to participate and substantial time delays due to principals being required in some instances to obtain approval from the school board of trustees. Lastly, we had a number of participants drop out prior to testing, due to family or sporting commitments.

Secondly, the sample for the study was relatively small and consisted of eight girls and four boys aged 8-13 years. Sample size was calculated based on the findings from previous cross-sectional studies in adolescents that found substantial differences in postprandial lipemia when assigning 8-15 subjects per cohort (36, 283, 300). Although girl-to-boy ratio was higher, it is argued that girls should be targeted as a priority group, because they are more sedentary than boys. However, it is important to note that results from this study should not be used to generalize results to wider populations. This study could be seen as a pilot study, the findings of which could provide a foundation for future larger scale studies.

Although this study was not randomized, it is strongly recommended that future studies are randomized. The benefit of participant randomization would ensure allocation bias is minimized, balancing both known and unknown predictive factors during both testing days. This would ensure that any effects are clinically significant (and may add further statistical power to findings) and reduce the probability of confounding factors.

Participant activity levels were monitored prior and during testing using ActivPAL accelerometers. Although ActivPAL accelerometers have been validated and are considered a reliable tool for measuring activity in adult populations (65), there is no published literature on their reliability in child populations. Unpublished research (67) piloted in lab-based and school-based experimental settings confirms that the ActivPAL is a reliable and valid tool for measuring activity in pre-adolescents. As highlighted in Chapter 2, there are a number of limitations to using accelerometers, including non-wear. Participants were asked to use daily log sheets to record the times the ActivPAL

was not worn, and the activity they were doing at the time. Although the accelerometers were water-proofed, they were removed at times during moderate to high intensity activity such as rugby or waterpolo games and also when participants were partaking in an activity where the device was considered aesthetically unpleasing (i.e during a ballet exam or clothes shopping). Non-wear time was removed during data cleaning, and this may have impacted the baseline percentage of time spent sedentary vs. active.

ActivPAL accelerometers were also used to measure the level of intensity (via cadence) of intermittent activity on day 1. Limitations of intermittent activity included weather variation such as rain, and access to suitable areas for play and duration of activity; for example the indoor fitness court was on two occasions booked out by another external client. Cadence results highlighted that all pre-adolescents participated in a moderate intensity during intermittent bouts however due to researcher to child ratio and pre-adolescents natural behavior, some pre-adolescents maintained a slightly more vigorous activity level. Activity choice also varied depending on time of day and weekend. It would be recommended that future studies implement an explicit plan to standardize activity, through perhaps the use of a treadmill where pre-adolescents walk or run at specified speeds. Plans need to remain similar during each testing weekend and contain a wet weather alternative.

A further consideration to this study was that there were a number of ethical considerations to be taken into account prior to the commencement of participant recruitment. In particular, main ethical concerns were blood withdrawal from pre-adolescents and the meal consumption. Research has highlighted that apprehension surrounding pain has been identified as one of the greatest fears for children (301). Due to the vulnerability of the participants in this study, participants were always fully informed of when blood removal was going to occur and maintained the opportunity to refuse blood withdrawal at any stage throughout the testing period, although this did not occur. Additionally, for parental comfort a registered paediatric nurse was on site for each testing session. In postprandial research typically only one baseline meal is consumed, but more recently a number of studies have opted to feed participant up to three days during a testing session. In this study, we continued to feed participants throughout the testing day to ensure 1) the postprandial response was maintained, 2) participants felt like they were in a safe and comfortable environment and 3) participants were not hungry. All additional meals simulated the timing of eating

patterns of pre-adolescents (morning tea, lunch and afternoon tea). If pre-adolescents felt full or unwell they were not encouraged to continue eating.

FUTURE DIRECTIONS

Future sedentary behavior and health research

The results of this study may provide initial evidence into the metabolic effects of sedentary behavior in pre-adolescents. However, it is recommended that further research should be conducted on a larger sample so that valid inferences from these findings can be made to populations.

Time spent in sedentary behavior has been linked to a number of deleterious health consequences, and therefore we would consider that our findings provide enough evidence for health practitioners and public health experts to begin to give serious consideration to endorsing reductions in sedentary behaviors.

In response to a number of published studies that emphasise the impact of sitting and associated negative health outcomes, Canada has released the Canadian Sedentary Behavior Guidelines for Children (aged 5–11 years) and Youth (aged 12–17 years) (302). The guideline recommendations state that for health benefits, children and youth should minimize the time that they spend being sedentary each day. This may be achieved by (i) limiting recreational screen-time to no more than two hours per day and (ii) limiting sedentary (motorized) transport, extended sitting time, and time spent indoors throughout the day. Although the guidelines are focused on decreasing time spent in specific sedentary activities, they do provide important and judicious recommendations to interrupt the overall time spent in sedentary behavior.

In addition, health experts agree that moderate- to vigorous- activity has a key preventative role in a number of lifestyle diseases, such as cardiovascular disease, type 2 diabetes and obesity. However, notwithstanding these benefits, it is important to remember a substantial number of pre-adolescents will continue to spend 80% of their day engaging in sedentary activities. As a consequence, putting in place initiatives to interrupt the time pre-adolescents spend in sedentary activity is important as encouraging the increase of regular moderate- to vigorous- activity internationally. As noted by Hamilton et al (5), communicating this new perspective to public policy-

makers will require some ingenuity and clarity. Interrupting the time that pre-adolescents spend in sedentary activity must be seen as a public health priority, but emphasis will also need to remain on ensuring pre-adolescents meet the current recommended activity guidelines.

CONCLUSIONS

Pre-adolescents spend a substantial proportion of their day engaged in sedentary pursuits. Studies which reported this group spending three or more hours per day in certain sedentary activities showed a positive correlation with lifestyle disease risks such as weight gain, obesity and low cardio-respiratory fitness. This study provided preliminary evidence to show that interrupting sedentary time may be key to decreasing lifestyle disease risks in healthy pre-adolescent children. The overall effects and conclusions from this thesis are outlined below:

- Time spent in sedentary activities has been positively associated with a number of negative health outcomes in pre-adolescents.
- While subjective and objective measures of sedentary behavior can provide measurement of time spent in sedentary behaviors, however there are a number of methodological issues that may substantially vary measured time spent sedentary.
- Interrupting sedentary time in eight pre-adolescent participants showed a clear reduction of TAG in comparison to continuous sedentary behavior. However, overall findings in pre-adolescent participants are unclear. Future studies should include a larger sample size.
- Interrupting sedentary activities may be key to improving future health in pre-adolescents and it is recommended that further research on the metabolic effects of intermittent activity is undertaken to support future activity policy changes.

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APPENDICES

APPENDIX A: PARTICIPANT COMPLIANCE LOG

For Office Use

CHILD RESPONDENT CODE: _____

Terms:
Wake Up = Eyes Open
Go to bed = Lights Out

CHILD LOG

Please complete the log below for your child for the next FOUR days starting from today.

Please circle any days when your child <u>did not</u> wear the motion sensors (ActivPal)	Starting Day 1 (Wednesday)	Day 2 (Thursday)	Day 3 (Friday)	Day 4 (Saturday)	Day 5 (Sunday)
For each day, what times were the motion sensor <u>not</u> worn (e.g., 1:00pm-2:45pm)?	ActivPal:	ActivPal:	ActivPal:	ActivPal:	ActivPal:
For each day, what was your child doing when they were <u>not</u> wearing the motion sensor?					
For each day, what time did your child wake up?					
For each day, what time did your child go to bed?					

APPENDIX B: PARTICIPANT FOOD QUESTIONNAIRE

Participant

Food Questionnaire

The questionnaire has been designed so we can gain an understanding of what you like or don't like to eat. Please tick the boxes if you **like and would want to eat** the foods listed.

Participant allergies (if any, please list below)

.....

.....

.....

Breakfast Foods

- | | |
|-----------------|--------------------------|
| Hash Browns | <input type="checkbox"/> |
| Croissants | <input type="checkbox"/> |
| Fried Eggs | <input type="checkbox"/> |
| English Muffins | <input type="checkbox"/> |
| Butter | <input type="checkbox"/> |
| Tomato Sauce | <input type="checkbox"/> |
| Peanut Butter | <input type="checkbox"/> |

Lunch Foods

- | | |
|----------------------------------|--------------------------|
| McDonalds Big Mac Burger | <input type="checkbox"/> |
| McDonalds Quarter Pounder Burger | <input type="checkbox"/> |
| Double Quarter Pounder | <input type="checkbox"/> |
| McDonalds French Fries | <input type="checkbox"/> |
| Fish & Chips | <input type="checkbox"/> |

Morning Tea & Afternoon Tea Foods

- | | |
|-------------------------------|--------------------------|
| Chocolate Biscuits | <input type="checkbox"/> |
| Nuts (Peanuts & Walnuts) | <input type="checkbox"/> |
| Moro Bar | <input type="checkbox"/> |
| Potato Chips (Salt & Vinegar) | <input type="checkbox"/> |
| Fruit (Bananas & Apples) | <input type="checkbox"/> |
| Crackers | <input type="checkbox"/> |

Drinks

- | | |
|-----------------------------|--------------------------|
| Milo (with Milk) | <input type="checkbox"/> |
| Milkshakes (with Ice cream) | <input type="checkbox"/> |
| Strawberry Primo | <input type="checkbox"/> |
| Chocolate Milk | <input type="checkbox"/> |

Other foods you like to eat are:

.....

.....

.....

.....

APPENDIX C: PARTICIPANT DAILY DIET

Participant Daily Meal

Meal	Food	Amount (serving)	Total Fats
Breakfast (8.30am)			89.1
	Burger, Double Quarter Pounder w/ Cheese	340g	50.32
	Potato, fries, McDonalds	1 medium serve	17.6
	Milk, fluid, whole	250 ml	10.22
	Milo, flavored, commercial drink	25g	0.86
	Potato, hash brown, McDonalds	1 piece	10.1
Morning Tea (10.10am)			
	Jelly tip Ice-cream		
	Snickers, bar	250g	34.5
		1 bar (12.1x3.1x1.9cm)	13.6
Lunch (12.30am)			41.31
	Butter, semi-soft	1 tsp	4.04
	Milk, fluid, whole	250 ml	10.22
	Milo, flavored, commercial drink	25g	0.86
	Croissant, filled with cheese & ham/bacon	1 filled croissant	26.2
Afternoon Tea (2.45pm)			38.63
	Doughnut, filled with fresh cream, sugar	1 doughnut	31.69
	Milk, UHT, chocolate flavor	300 ml	6.94
Other (Snacks)	Chocolate Biscuits		
	Fruit		

APPENDIX D: LETTER OF RECOMMENDATION TO PARENTS



Dear Parent,

Hopefully today your child had plenty of fun and enjoyed themselves while participating in their first testing session! They had the opportunity to watch movies, play playstation, and computer games, read and draw. Additionally every thirty minutes they were up running around, skipping and exercising!

This letter is to inform you that your child did undergo five-finger pricks over the course of today. Finger pricking does cause very small superficial wounds and although the pain and potential anxiety was minimised as much as possible there could possibly be a bit of sensitivity to the finger areas for the next few hours or days. In some circumstances slight bruising will occur and this is very natural.

If possible it would be best to leave the fingers un-bandaged to assist in the healing process.

Your child also ate a diet high in fat today. We strongly recommend that their evening meal tonight is low in fat and has plenty of fruit and veges. This will also ensure your child meets the National Food and Nutrition Guidelines set by the Ministry of Health because their diet today limited the fruit and vege intake they consumed. Please do not be alarmed if your child is not hungry! Because of the large volume of food they consumed today this will be a very common side effect.

Please remember, you can contact me at any time (txt, phone or email) if you have any questions or queries.

I will be in touch later next week to again for next weekend's session.

Enjoy your evening,

Kara Faithfull

Researcher

kara.faithfull@aut.ac.nz

APPENDIX E: DATA COLLECTION SHEET

Participant Data Collection Sheet

Participant:

		Sample Taken (circle)	Child administered own sample?	Child's Response (Circle)	Further Comments:
8.40am	T1P1	YES / NO	YES / NO	Enjoyed / Liked / Disliked / Refused	
10.50am	T2P1	YES / NO	YES / NO	Enjoyed / Liked / Disliked / Refused	
12.50pm	T3P1	YES / NO	YES / NO	Enjoyed / Liked / Disliked / Refused	
2.50pm	T4P1	YES / NO	YES / NO	Enjoyed / Liked / Disliked / Refused	
4.00pm	T5P1	YES / NO	YES / NO	Enjoyed / Liked / Disliked / Refused	

APPENDIX F: PARTICIPANT INFORMATION SHEET

Child Information Sheet

An Invitation



Date Information Sheet Produced: 24 July 2010

Project Title:

The Effect of Sitting time and Diet in Children

Dear Participant,

My name is Kara Faithfull, and I am completing studying AUT University.

This is an invitation for you to join in the Effect of Sitting time and Diet in Children Project at your School. We thank you for considering joining in this research project and encourage you to read the following information sheet carefully to ensure you met the criteria before deciding to take part. Your participation is voluntary and you may withdraw at any time prior to the completion of data collection. If you have any questions please feel free to contact me at any stage.

How Was I chosen for this invitation?

The Effect of Sitting time and Diet in Children Project is inviting all Year 7 & 8 children from your school to participate. As part of the study you will be asked to wear two accelerometers for three days and participate in two testing sessions measuring the effect of sitting time over two consecutive Saturdays. All children consenting to join in the study will have their height and weight measurements taken.

Am I eligible to participate?

- You will need to be between 11 to 12 years of age.
- You will need to have a body mass index (BMI) of 17-24.
BMI= Weight (kgs) divided by Height (cm) squared.
- You must not be doing lots of physical activity.
- You will need to have no current health conditions.

What is the purpose of this research?

We are interested in finding out the effect of sitting has on your health. We know children who are physically active every day; walking to school, doing chores, being

involved in sports and playing are often healthier than those who don't and hope that the research will help to provide answers to encourage more people to be active.

What will happen in this research?

Part One

Initially, the researcher will make a visit to your home to collect the following information: Name, Age, Ethnicity, Gender, Height, and Weight, of your child.

Then we will need to gauge the level of physical activity you do. You will be asked to wear a small device called the ActivPal inclinometer, worn on the front of the thigh. The device can measure time spent sitting, standing and walking. In addition, the Actical Accelerometer, worn around the waist, is a small computer used to measure children's physical activity levels. We will ask you to wear the devices for three days (two weekday and 1 weekend day) to accurately gauge your current physical activity level. The researcher will be contactable at all times over the three days if you need to get in contact with her.



ACTICAL ACCELEROMETER



ACTIVPAL

INCLINOMETER

The accelerometers store the number of activity counts or movements you make and count the number of steps a child takes when they are active. The accelerometer records the amount of steps taken each minute of the day and the number of activity counts or movements' you make every 15 seconds. Both devices will work together to make sure we get an accurate understanding of your physical activity. The researcher then downloads the stored activity and step counts on to a computer for analysis. The software provides graphs of your physical activity levels over the three days.

The data we collect will only be shared with your family.

Part two

After completing three days of measurement we will ask you to attend two testing sessions at AUT University of Technology, North Shore Campus on two nominated Saturdays. Due to the study design you will be required to give blood at two hour intervals throughout the testing sessions. We will try to make this as comfortable as possible for you.

What happens on the testing day?

On the first Saturday testing session you will be required to remain sitting for the entire session and will have the opportunity to watch TV, play computer games, read and or some drawing. If you would like to bring your own activities, this should also be fine but please talk with the researcher. Then every 30-minuted we will interrupt your activity with a small burst of physical activity for 4 minutes. Again you can choose an activity of their choice (skipping, hallway runs, aerobics, and dancing).

At two-hour intervals we will perform a small finger prick on the side of your finger to measure your cholesterol, triacylglycerol TAG and glucose levels. However, we also encourage you (if you want too) to administer your own finger prick- this will be supervised by a registered nurse. On an hourly basis blood pressure will be taken.

On the second Saturday you will again be asked to assume sitting activities of their choice, At two hour intervals we will perform a small finger prick on the side of your finger to measure your cholesterol, triacylglycerol TAG and glucose levels, again you will have the opportunity to self administer the prick. On an hourly basis blood pressure will be taken. You will be required to remain sitting for the whole day.

During both testing days and at set times you will have the opportunity to eat a variety of foods. You will receive a breakfast, morning tea, lunch and afternoon tea that are appropriate to your energy requirements. Everyone will be able to drink water throughout the session. The diet will be made to consider any of your allergies, likes and dislikes. Due to the nature of testing a registered nurse will be present with you on the rounds during each 8-hour period.

What are the benefits to me?

Each child and their family will receive an individualised risk factor profile highlighting your child's current levels of activity. You will also receive a physical activity pack aimed to encourage positive physical activity behavior s. All Children will receive a small gift for their participation as a thank-you. You will also have the opportunity to eat lots of yummy food and watch movies or engage in sitting activities of your choice on each testing day.

What are the discomforts and risks I may have?

Everybody is different, but we have listed some of the things that may happen. You may be embarrassed or upset when having body weight and other measurements taken so these measurements are taken separate from others, in the presence of the parent/legal guardian and the results are kept private. A female and male researcher will be present when any measurements are taken.

There is also a very small physical discomfort involved during testing. Finger pricks generally last for less than three seconds (including blood withdraw) however the pain may stay around for up to 2 minutes after each prick and in some cases slight bruising may occur. To reduce as much discomfort as possible we will allow you to administer your own finger pricks (fully supervised), this option is being provided to alleviate any psychological stress that may occur. If you do not wish to self-administer the finger pricks the trained researcher will take each sample. After each prick you will receive a sticker.

What compensation is available for injury or negligence?

In the unlikely event of a physical injury as a result of your participation in this study, rehabilitation and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation's regulations. Please talk to the researcher or your parents if you are upset or are worried about anything.

What do I do if I have concerns about this research?

Please talk to your mum or dad about your concerns so they are able to contact the researcher.

Kara Faithfull, kara.faithfull@aut.ac.nz 0274049702 or Madeline Banda, madeline.banda@aut.ac.nz, 921 9999 ext 8044.

What happens if I lose or break the equipment?

If for any reason the device supplied is lost or damaged there will be no financial consequences placed on you or your family.

What happens if I want to participate but can't make the nominated Saturday?

Please talk this over with the researcher and they should be able (depending on availability) fit you in on another Saturday.

How do I agree to participate in this research?

You will be required to sign the attached assent form and have your parent/legal guardian sign the consent form. Signing the consent form indicates that you have given your assent freely to join the Effect of Sitting time and Diet in Children Project and that there has been no coercion or inducement to allow you to join. We encourage you to contact the researcher if you have any questions.

Whom do I contact for further information about this research?

Principal Investigator contact details:

Kara Faithfull

School of Sport & Recreation

Faculty of Health Sciences

AUT University, North Shore Campus

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Supervisor:

Dr Erica Hinckson

Head of Research

School of Sport & Recreation

Erica.hinckson@aut.ac.nz

Approved by the Auckland University of Technology Ethics Committee on 15 September 2010, AUTEK Reference number 10/179

APPENDIX G: PARENT/GUARDIAN INFORMATION SHEET

Parent Information Sheet

An Invitation



Date Information Sheet Produced: 24 July 2010

Project Title: The Effect of Sitting time and Diet in Children

Dear Parent/legal guardian and Participant,

My name is Kara Faithfull, and I am completing my Master's in Health Science (Sport & Physical activity) at AUT University.

This is an invitation for you and your child, to join in the Effect of Sitting time and Diet in Children Project at your School. We thank you in advance for considering joining in this research project and encourage you to read the following information sheet carefully to ensure you met the criteria before deciding to take part. Your participation is voluntary and you may withdraw at any time prior to the completion of data collection. If you have any questions please feel free to contact me at any stage.

How were we chosen for this invitation?

The Effect of Sitting time and Diet in Children Project is inviting all Year 7& 8 children from your school to participate. As part of the study your child will be asked to wear two accelerometers for three days and participate in two testing sessions measuring the effect of sitting time over two consecutive Saturdays. All children consenting to join in the study will have their height and weight measurements taken.

What are the Participation Criteria?

- Your child will need to be between 11 to 12 years of age.
- Your child will need to have a body mass index (BMI) of 17-24.
- Your child must not be engaging in regular strenuous activity.
- Your child will need to have no current health conditions.

What is the purpose of this research?

Researchers are interested in determining accurately how much of an effect sitting has on predictors of lifestyle diseases such as obesity and cardiovascular disease. We know

children who are physically active every day; walking to school, doing chores, being involved in sports, playing and spending minimal time using electronic media (TV, computer games and console games) have much better health and fitness than those who don't and hope that the research will help to provide answers to decrease life style disease risk factors in children. The aim of the study is to determine the effect of interrupting sitting time on postprandial plasma triacylglycerol (TAG) concentrations (atherosclerosis marker) in children. This means we would like to investigate how sitting time effects the amount of fat found in the blood system after periods of sitting.

What will happen in this research?

Part One

Initially, we will ask that you provide the height and weight details for your child on the parental consent form. If your child matches the criteria on page one the researcher will make a visit to your child at your home to collect the following information: Name, Age, Ethnicity, Gender, of your child.

Then we will need to gauge the level of physical activity your child does. Your child will be asked to wear a small device called the ActivPal inclinometer, worn on the front of the thigh. The device can measure time spent sitting, standing and walking. In addition, the Actical Accelerometer, worn around the waist, is a small computer used to measure children's physical activity levels. We will ask your child to wear the devices for three days (two weekday and 1 weekend day) to accurately gauge their current physical activity level. The researcher will be contactable at all times over the three days if any issues arise.



ACTICAL ACCELEROMETER



ACTIVPAL

INCLINOMETER

The accelerometers store the number of activity counts or movements children make and count the number of steps a child takes when they are active. The accelerometer records the amount of steps taken each minute of the day and the number of activity counts or movements' children make every 15 seconds. Both devices will work together to ensure both sitting time and physical activity is accurately measured. The researcher

then downloads the stored activity and step counts on to a computer for analysis. The software provides graphs of your children's physical activity levels over the three days. Information and any data collected will be available to parents or legal guardians. However, the information collected is confidential between the researchers, child and parent or legal guardian and will not be disclosed to any other persons.

Part two

After completing three days of measurement we will ask your child to attend two testing sessions at AUT University of Technology, North Shore Campus on two nominated Saturdays. Due to the study design your child will be required to give blood at two hour intervals throughout the testing sessions. This will measure the amount of fat found in the blood stream.

Testing will be held in the months October 1st – December 5th 2010. Each child will be required to attend two consecutive Saturday testing sessions. Weekends have been chosen to ensure that your child is not taken away from school class time. All children will be required to be at the Institute at 8.30am on the Saturday mornings after a 12 hour period of fasting for a de-briefing and will be required to remain until 4pm. Parents/legal guardians will be issued with a \$20 petrol voucher to assist in getting to the testing venue.

What happens on the testing day?

On the first Saturday testing session your child will be required to remain sitting for the entire session whilst immersed in sedentary activities (TV watching, computer games, reading, drawing). They may choose the activities they which to partake in and are even welcome to bring their own activities if they wish (in discussion with researcher). Then at 30-minute intervals all sedentary activities will be interrupted with a small burst of physical activity for 4 minutes. Again your child can choose an activity of their choice (skipping, hallway runs, aerobics, and dancing).

At two-hour intervals we will perform a small finger prick on the side of the child's finger to measure their cholesterol, triacylglycerol TAG and glucose levels. However, we also encourage the child if they are more comfortable, with administering their own finger prick- this will be supervised by a registered nurse. On an hourly basis blood pressure will be taken.

On the following Saturday children will again be asked to assume sedentary activities of their choice, At two hour intervals we will perform a small finger prick on the side of the child's finger to measure their cholesterol, triacylglycerol TAG and glucose levels, again your child will have the opportunity to self administer the prick. On an hourly basis blood pressure will be taken. All children will remain sedentary for the whole day. During both testing days and at set times your child will have the opportunity to eat a variety of foods. All children will receive a breakfast, morning tea, lunch and afternoon tea that are appropriate to their energy requirements. All children will be able to drink water throughout the session. The diet will be made in consultation with a qualified AUT dietician and will consider any child's allergies, likes and dislikes. Due to the nature of testing a registered nurse will be present on the rounds during each 8-hour period.

What are the benefits to us?

Each child and their family will receive an individualised risk factor profile highlighting your child's current levels of activity. Your child will also receive a physical activity pack aimed to encourage positive physical activity behavior s. All Children will receive a small gift for their participation as a thank-you. Children will also have the opportunity to eat lots of yummy food and watch movies or engage in sedentary activities of their choice on each testing day.

What are the discomforts and risks you child may have?

Your child may be embarrassed or upset when having body weight and other measurements taken so these measurements are taken separate from others, in the presence of the parent/legal guardian and the results are kept private. A female and male researcher will be present when any measurements are taken.

There is also a very small physical discomfort involved during testing for all children through blood collection. Finger pricks generally last for less than three seconds (including blood withdraw) however the acute pain may stay around for up 2 minutes after each prick and in some cases slight bruising may occur. To reduce as much discomfort as possible we will allow the children to administer their own finger pricks (fully supervised), this option is being provided to alleviate any psychological stress children may have. If you child does not wish to self-administer the finger pricks the trained researcher will take each sample. After each prick the participant will receive a sticker.

How will these discomforts and risks be alleviated?

To minimise risk of harm to children joining in the study even further (i) all persons collecting measurements will be experienced, (ii) all measurements will be taken separate from other children and the results are kept private with two researchers present at all times. A female researcher will perform measurements on females. Participants will be able to choose which researcher they would like to take the measurements. (iii) All information will be confidential between the child, parent or legal guardian and all researchers. (iv) Parents and whanau can be present when measurements on their child are undertaken.

What compensation is available for injury or negligence?

In the unlikely event of a physical injury as a result of your participation in this study, rehabilitation and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation's regulations.

How will our privacy be protected?

-All personal information, questions, answers and results from this study will be treated as confidential and will be handled in accordance with the principles of the Privacy Act 1993.

-The identity of children will be protected at all stages of the project.

Information will be kept secure by the following processes.

-Individuals involved in collecting information will be required to sign a confidentiality agreement.

-Identifying information will be removed from documents.

-Forms will be kept in a secure location at AUT and separately from data collected.

-Data will be entered and stored directly onto password protected electronic databases.

-Parents and legal guardians of children can have access to all stored information relating to your child.

-Only information necessary for the purposes of this study will be collected.

Data will not be shared with any other third party that is not directly involved with the project.

What are the costs of participating in this research?

There are no monetary costs to parents in the Effect of Sitting time and Diet in Children Project. Children will be required for approximately 15 minutes for the taking of measurements in the beginning of the project when receiving the accelerometers to wear. Over the measurement period of 3 days children will also be required to wear both motion sensors. The motion sensors will be dropped off and picked up from your residence. Correct fitting and instruction will be given to parent/legal guardian of each child. Your child will then be asked to spend 2 consecutive Saturdays at the Millennium Institute of Sport & Health. Both days will be 7.5 hours long and a \$20 petrol voucher will be issued to the parents to assist with getting to the venue. Each participant will be feed a breakfast, morning tea, lunch and afternoon tea on each testing day.

Will I receive feedback on the results of this research?

Parents or legal guardians will receive a short report of your child's results within 6 weeks of completing the study measurements. The reports will include a preliminary summary of findings. Stakeholders including school representatives, legal guardians and parents will be offered copies of journal articles about the study. No personal information or personal results will be discussed or divulged in publications. A second more comprehensive summary of findings will be forwarded to parents or legal guardians on completion of the project (June 2011).

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Researcher, Kara Faithfull, kara.faithfull@aut.ac.nz, 0274049702.

Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTECH, Madeline Banda, madeline.banda@aut.ac.nz 921 9999 ext 8044.

What happens if I lose or break the equipment?

If for any reason the device supplied to the child is lost or damaged there will be no financial consequences placed on the parent/ legal guardian.

What happens if we want to participate but can't make the nominated Saturday?

Please talk this over with the researcher and they should be able (depending on availability) fit you in on another Saturday.

How do I agree to participate in this research?

Your consent to allow your child to join in the Effect of Sitting time and Diet in Children Project will be indicated by signing the consent form attached. Signing the consent form indicates that you have given your consent freely to join the Effect of Sitting time and Diet in Children Project and that there has been no coercion or inducement to allow your child to join. Full consent for your child to join in the Project is conditional on your child also agreeing to join. We encourage you to contact the researcher if you have any questions.

Whom do I contact for further information about this research?**Principal Investigator Contact Details:****Kara Faithfull**

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Supervisor:**Dr Erica Hinckson**

Head of Research
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Approved by the Auckland University of Technology Ethics Committee on 15 September 2010, AUTEK Reference number 10/179

APPENDIX H: PARTICIPANT ASSENT FORM

Assent Form



Project title: ***Effect of Sitting time and Diet in Children***

Project Supervisor: ***Dr Erica Hinckson***

Researcher: ***Kara Faithfull***

- ☐ I have read and understood the sheet telling me what will happen in this study and why it is important.
- ☐ I understand that while the information is being collected, I can stop being part of this study whenever I want and that it is perfectly ok for me to do this.
- ☐ I have been able to ask questions and to have them answered.
- ☐ I understand that I will receive a small finger prick every second hour to measure their triacylglycerol, glucose, cholesterol and chylomicrons levels and I have happy about this.
- ☐ If I stop being part of the study, I understand that all information about me, will be destroyed.
- ☐ I agree that I am happy to take part in this research

Participant's signature:

.....

Participant's name:

.....

Participant Contact Details (if appropriate):

.....
.....
.....
.....

Date:

***Approved by the Auckland University of Technology Ethics Committee on 15
September 2010 AUTEK Reference number 10/179***

Note: The Participant should retain a copy of this form.

APPENDIX I: PARENT/GUARDIAN CONSENT SHEET

Parent/Guardian Consent Form



Project title: Effect of Sitting time and Diet in Children

Project Supervisor: Dr Erica Hinckson

Researcher: Kara Faithfull

- ☐ I have read and understood the information provided about this research project in the Information Sheet dated 01/08/2010.
- ☐ I have had an opportunity to ask questions and to have them answered.
- ☐ I understand that the researchers will analyse my child's physical activity levels by downloading 3 days' data from the motion sensors (ActivPal and Actical accelerometers).
- ☐ I understand the motion sensors are expensive and every care will be taken to ensure that they are returned to the researcher at the end of this study.
- ☐ I understand the motion sensors are waterproof and do not have to be removed when the child is showering or undertaking water based activities.
- ☐ I understand that although the equipment is expensive and valuable that there will be no financial consequences if my child loses/breaks the supplied equipment.
- ☐ I understand my child will be required to attend two testing sessions each 7.5 hours long on consecutive Saturdays at the AUT University, North Shore Campus and I will be provided with a \$20 fuel voucher to assist with this.
- ☐ I understand that my child will be required to fast for 12 hours prior to the testing and maintain low physical activity levels.
- ☐ I have let the researcher know of any food allergies my child may have.
- ☐ I understand that my child will be feed Breakfast, Morning Tea, Lunch and Afternoon Tea on both testing days.
- ☐ I understand that my child will receive a small finger prick every second hour to measure their triacylglycerol, glucose, cholesterol and chylomicrons levels and I have discussed this fully with my child.
- ☐ I understand that if I may have all my child's blood samples returned at the completion of each testing if I wish.

- ☐ I understand that I may withdraw my child/children's data or any information that we have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.
- ☐ If my child/children and/or I withdraw, I understand that all relevant information will be destroyed.
- ☐ I agree to my child/children taking part in this research.
- ☐ I wish to receive a copy of the report from the research (please tick one):
Yes ☐ or No ☐

My Childs Height is.....

My Child's Weight is.....

Child's name :

.....
.....

Parent/Guardian's signature:

.....

Parent/Guardian's name:

.....

Parent/Guardian's Contact Details (if appropriate):

.....
.....
.....
.....

Date:

Approved by the Auckland University of Technology Ethics Committee on 15 September 2010, AUTECH Reference number 10/179

Note: The Participant should retain a copy of this form.

APPENDIX J: APPROVAL LETTER FROM ETHICS COMMITTEE



M E M O R A N D U M
Auckland University of Technology Ethics Committee (AUTEC)

To: Erica Hinckson
From: **Madeline Banda** Executive Secretary, AUTEC
Date: 15 September 2010
Subject: Ethics Application Number 10/179 **Effect of sitting time and diet in children.**

Dear Erica

Thank you for providing written evidence as requested. I am pleased to advise that it satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC) at their meeting on 9 August 2010 and that I have approved your ethics application. This delegated approval is made in accordance with section 5.3.2.3 of AUTEC's *Applying for Ethics Approval: Guidelines and Procedures* and is subject to endorsement at AUTEC's meeting on 11 October 2010.

Your ethics application is approved for a period of three years until 15 September 2013.

I advise that as part of the ethics approval process, you are required to submit the following to AUTEC:

- A brief annual progress report using form EA2, which is available online through <http://www.aut.ac.nz/research/research-ethics/ethics>. When necessary this form may also be used to request an extension of the approval at least one month prior to its expiry on 15 September 2013;
- A brief report on the status of the project using form EA3, which is available online through <http://www.aut.ac.nz/research/research-ethics/ethics>. This report is to be submitted either when the approval expires on 15 September 2013 or on completion of the project, whichever comes sooner;

It is a condition of approval that AUTEC is notified of any adverse events or if the research does not commence. AUTEC approval needs to be sought for any alteration to the research, including any alteration of or addition to any documents that are provided to participants. You are reminded that, as applicant, you are responsible for ensuring

that research undertaken under this approval occurs within the parameters outlined in the approved application.

Please note that AUTECH grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to make the arrangements necessary to obtain this.

When communicating with us about this application, we ask that you use the application number and study title to enable us to provide you with prompt service. Should you have any further enquiries regarding this matter, you are welcome to contact Charles Grinter, Ethics Coordinator, by email at ethics@aut.ac.nz or by telephone on 921 9999 at extension 8860.

On behalf of the AUTECH and myself, I wish you success with your research and look forward to reading about it in your reports.

Yours sincerely



Madeline Banda

Executive Secretary

Auckland University of Technology Ethics Committee

Cc: Kara Faithfull kara.faithfull@aut.ac.nz

APPENDIX K: COHEN'S D EQUATION

Cohen's d equation

$$s = \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2}},$$
$$s_1^2 = \frac{1}{n_1 - 1} \sum_{i=1}^{n_1} (x_{1,i} - \bar{x}_1)^2$$

Figure A.1. Cohen's d effect size equation

s = standard deviation

s_1^2 = standard deviation of group 1 (intermittent sitting)

s_2^2 = standard deviation of group 2 (intermittent sitting)

n_1 = sample size of group 1

n_2 = sample size of group 2

x_1 = mean of group

= mean of individual observation

APPENDIX L: RELIABILITY OF THE ACTIVPAL INCLINOMETER IN DETERMINING SITTING, STANDING AND STEPPING TIME IN NEW ZEALAND CHILDREN.

The following pages comprise the following paper submitted to the Journal of Physical Activity and Health. “Reliability of the ActivPAL inclinometer in determining sitting, standing and stepping time in New Zealand children” *Manuscript submitted for publication.*

This paper has been included in the Appendices as it’s findings substantially impacted the design of this Master’s thesis and includes co-authored research.

Reliability of the ActivPAL inclinometer in determining sitting, standing and stepping time in children

Abstract

Accurate quantification of sitting is now possible with the ActivPAL monitor, worn on the thigh and incorporating an inclinometer to sense limb position. **Purpose:** To determine reliability and quantify daily habitual activity in children wearing an ActivPAL monitor. **Methods:** Fifty-six children (age 10.2 ± 0.9 y, mean \pm SD) were randomly recruited from 30 urban schools. Analyses were performed with mixed modeling. Reliability was expressed as within-subject errors and intraclass correlation coefficients (ICC). Data were collected between August 2009 and June 2010 in Auckland, New Zealand. **Results:** Overall, daily percent mean time spent sitting/lying, standing and stepping on weekdays and weekend days for girls and boys were $\sim 78 \pm 5$, 14 ± 3 , and 8 ± 2 (mean \pm SD); changes in activity between weekdays and weekend days were typically small, with more sitting/lying and less activity in weekends; girls stood more and stepped less than boys. Within-subject wk-to-wk variability in percent time spent sitting/lying, standing and stepping was ~ 3.5 , ~ 2.5 and ~ 1.5 . Intraclass correlation coefficients ranged 0.36 to 0.69. **Conclusion:** Children spend over half their time sitting/lying. Interventions aimed at a moderate reduction in sitting time (~ 5 percent of the day) will require modest sample sizes for adequate precision.

Key words: accelerometer, ActivPAL, habitual, physical activity, sedentary

Introduction

Over the last several decades, physical activity in children has progressively decreased ((303, 304)) and sedentary behavior, quantified as "screen-time", has increased considerably as a result of technological advancement and economic development ((304, 305)). Emerging evidence suggests that, notwithstanding the protective effects of activity on such diseases as obesity, type 2 diabetes, cardiovascular disease, breast cancer and colon cancer, there may be harmful metabolic and health effects from extended periods of sedentary time ((306, 307)). Interrupting sedentary time by incorporating frequent transitions from sitting to standing and bouts of walking, benefits metabolic health in adults ((308)), but there has been little research with children ((307)).

Children are naturally active, but they are continually exposed to opportunities and environments that cause them to be sedentary ((304, 305)). Sedentary behavior includes any activity that involves prolonged sitting and requires little energy expenditure ((309)). For children, sedentary behavior can include activities of sitting in the classroom, sitting during lunch time, sitting and not participating in physical education classes, watching tv, playing computer games, homework, and passive transport.

Sedentary behavior in childhood is associated with overweight, poor fitness, and raised cholesterol in adulthood ((310)). Robinson et al. ((311)) showed that reducing specific sedentary behaviors may be a promising approach to preventing childhood obesity. Others have shown that when sedentary behavior was targeted in obese children there were equal or better changes in weight compared to those who were encouraged to be physically active ((312, 313)).

Sedentary behavior was previously assumed as "activity absence" but more recently, researchers have objectively assessed sedentary behavior via accelerometry ((314, 315)). However, researchers were unable to differentiate between sitting and standing. Accurate quantification of sitting time is now possible with new generation accelerometers that include an inclinometer. The ActivPAL monitor, worn on the thigh incorporating an inclinometer to sense limb position is one such accelerometer. The first step to understanding sedentary behavior in children is to accurately and objectively assess it in various settings. Therefore, the aims of this study were to quantify time spent in sitting in children and determine wk-to-wk variability using the ActivPAL monitor.

This study is the first to quantify time spent in sedentary behavior in children over 24-hour days for 14 days.

Participant recruitment and study design

Using a stratified two stage sampling approach, 64 children (9-10 years of age) were recruited from elementary schools (low, mid and high socioeconomic areas) from across the Auckland region (North, Central, South/East and West Auckland). Thirty schools were randomly selected and from each school two to three children were recruited. Elementary schools that were public and within the borders of the Auckland Region were included in the study. Currently, there are 75 elementary schools in North Shore City (North Auckland), 131 in Manukau City (South/East Auckland), 159 in Auckland City (Central Auckland) and 73 in Waitakere City (West Auckland). Participant characteristics are presented in Table A.1. The study was approved by the Institution's ethics committee. Upon receipt of consent forms from parents/legal guardians and assent forms from children, researchers visited the children's homes on four occasions. On the first visit height and weight were measured with children dressed in light clothing. Height was measured using a portable stadiometer. Weight was measured with a standard physician's scale according to ISAK protocols ((316)). Body mass index (BMI) was calculated as body weight in kilograms divided by height in meters squared. In addition, children were outfitted with an ActivPAL (PAL Technologies Ltd, Glasgow, UK) worn on the thigh in a waterproof pouch secured by an elastic velcro belt (Figure A.1). Children and their parents received detailed instruction regarding the use of the monitor. Children were instructed to wear the monitor all day for 7 days. A log sheet was also provided for instances where the monitor was taken off to identify those specific times. On the second visit (7d later), the monitor was removed and taken to the laboratory for downloading and quick review of the data. The participants and their families were asked to comment on their experience wearing the monitor. On the third visit (2-3d later) the monitor was returned and refitted for the children. On the last visit (7d later), the monitor was collected for the last time and a small gift and certificate of completion was given to the children. Data were collected between August 2009 and June 2010 and final analysis was completed in January 2011.



Figure A.2. The ActivPAL monitor, silicon pocket and water-resistant Velcro belt. The ActivPAL monitor unit is placed on anterior mid-thigh section.

Measurement of sedentary behavior and postural allocation

Objective assessment of sitting/lying, standing, stepping and transitioning was obtained with the ActivPAL monitor. The ActivPAL™ (PAL Technologies Ltd, Glasgow, UK) is a light monitor (5 x 3.5 x 0.7 cm) worn on the front of the thigh. It is a uni-axial accelerometer and responds to signals related to gravitational forces and thigh inclination. The ActivPAL™ measures acceleration at a sampling frequency of 10Hz (one reading of acceleration every 10⁻¹ of a second). The monitor can provide the actual acceleration in real time. In a range 1-254, 3 is approximately 0g and 150 is about 1g. The ActivPAL™ software takes this signal and analyzes it to produce a record of the activity events (sitting/lying, standing, stepping). The activities undertaken can be summarized in 15s intervals (epochs). The acceleration intensity over the 15s period summarized by taking the acceleration signal (at 10Hz), so 150 samples in 15s, and sum the absolute difference between each sample (absolute is used to sum as otherwise the sum of the differences would tend to zero) ((317)). As per manufacturer instructions, the participants were instructed to wear the monitor on the mid-line of the thigh, one third of the way between hip and knee. Each ActivPAL™ monitor was tested for functionality and accuracy.

Statistical Analysis

Mixed modeling (version 9.2, SAS Institute, Cary, NC) was used to estimate means and SD representing within- and between-subject variability for sitting/lying, standing and stepping, step counts and sit-to-stand counts during week and weekend days. Variance

components were estimated for identity (between-subject), residual (within-subject) and combined to give the observed between SD. Reliability was expressed as intraclass correlation coefficients (ICC), estimated as the between-subject variance divided by observed variance. Confidence limits for the typical errors (within-subject standard deviations) were provided by Proc Mixed. Confidence limits for the ICC were derived via the between-subject/within-subject variance ratio, which has an F sampling distribution. Uncertainty in effects and random errors were expressed as 90% confidence limits. Changes in the mean comparison between girls and boys were interpreted using magnitude-based inferences ((318)). The magnitudes of the standardized effects (difference in the change score and uncertainty were standardized using the mean SD adjusted for sample size bias) were interpreted with a modification (to account for very large effects) ((318)) of Cohen's scale ((319)) for such effects: trivial <0.20 ; small $0.20-0.59$; moderate $0.60-1.19$; large ≥ 1.20 . Periods were used to identify the segment in the day where children were sitting/lying the most. The periods for a weekday were: Sleep, 22:00-5:59; Before school, 6:00-7:59; Morning travel, 8:00-8:59; School, 9:00-14:59; Afternoon travel, 15:00-15:59; After school, 16:00-19:59; Evening, 20:00-21:59. The periods for a weekend day were: Sleep, 22:00-5:59; Early am, 6:00-8:59; Morning, 9:00-11:59; Afternoon, 12:00-15:59; Late afternoon, 16:00-19:59; Evening, 20:00-21:59. To get an accurate picture for the reliability analysis, sleep/lying was included in the analysis for two main reasons: i) 24-h data from participants provided an accurate picture of the day's activities; and ii) while periods were defined previously, they were artificially created, consequently if we removed sleep the data will no longer be representative, e.g some children go to sleep later in the night and wake up later in the day before school.

Results

Descriptive characteristics of participants who provided data for the analysis are summarized in Table A.1. Boys and girls had similar values for age, weight, height and BMI. Europeans had higher representation than expected (67% girls, 70% boys); the ethnic mix in the Auckland region is 56% European as per 2006 Census data ((320)).

Table A.1. Descriptive characteristics (mean \pm SD) for the elementary school children in Auckland New Zealand (2009-2010).

	Girls	Boys
	(N=28)	(N=28)
Age (yr)	10.0 \pm 0.8	10.3 \pm 0.9
Weight (kg)	37.4 \pm 8.8	37.5 \pm 7.9
Height (m)	140.3 \pm 8.0	141.3 \pm 4.9
BMI (kg.m ⁻²)	18.8 \pm 3.0	18.7 \pm 3.2

Means and standard deviations for daily sitting/lying, standing, stepping, step counts, and transition counts in different periods during week and weekend days are presented in Table A.2. The footnote for the table shows approximate confidence limits for the comparison of the school period with other periods, to illustrate the uncertainty expected with the sample size in this study.

During weekdays time spent sitting/lying during sleep was 96 \pm 12 for girls and 99 \pm 1 for boys. Apart from sleep and evening periods, time spent sitting/lying was highest before and after school, followed by school periods. Time spent standing was highest primarily during morning and afternoon travel. Time in stepping peaked during morning travel and declined over the course of the day. Most sit-to-stand transitions were observed at school for both girls and boys and after school for boys. Most energy expended over the course of the day was observed during morning travel.

During the weekend, time spent sitting/lying was 98 \pm 9 for girls and 98 \pm 5 for boys. Time spent sitting/lying was highest during early morning followed by late afternoon. Time spent standing was highest in the morning for the boys and most step counts were taken in the afternoon for both boys and girls. Boys accumulated more step counts than girls. Most sit-to stand transitions were observed in the morning for the girls and afternoon for the boys and most energy was expended in the afternoon period.

Table A.2. Daily sitting, standing, stepping, step counts and sit-to-stand counts during periods of weekday and weekend days for girls (G) and boys (B) in Auckland, New Zealand (2009-2010). Data are mean \pm SD.

		Sitting	Standing	Stepping	Step	Sit-to-stand
		(%)	(%)	(%)	count (h⁻¹)	counts (h⁻¹)
Weekday Periods^a						
Sleep	G	96 \pm 12	4 \pm 12	0.1 \pm 0.3	5 \pm 13	0.1 \pm 0.3
	B	99 \pm 1	1 \pm 1	0.2 \pm 0.2	7 \pm 10	0.2 \pm 0.3
Before School	G	68 \pm 15	22 \pm 11	10 \pm 6	500 \pm 320	4.8 \pm 1.8
	B	72 \pm 17	18 \pm 11	10 \pm 7	490 \pm 370	4.5 \pm 2.2
Morning travel	G	55 \pm 17	27 \pm 10	18 \pm 9	950 \pm 520	5.8 \pm 2.3
	B	59 \pm 17	22 \pm 9	19 \pm 11	970 \pm 560	5.9 \pm 2.3
School	G	62 \pm 8	22 \pm 6	15 \pm 3	760 \pm 170	6.9 \pm 1.6
	B	59 \pm 9	23 \pm 6	18 \pm 4	880 \pm 200	7.1 \pm 1.7
Afternoon travel	G	59 \pm 14	24 \pm 9	17 \pm 8	860 \pm 450	6.8 \pm 2.3
	B	61 \pm 13	22 \pm 8	17 \pm 8	840 \pm 450	6.2 \pm 2.3
After school	G	67 \pm 11	23 \pm 8	10 \pm 4	480 \pm 190	7.0 \pm 1.9
	B	65 \pm 11	21 \pm 6	14 \pm 6	630 \pm 310	5.9 \pm 1.4
Evening	G	87 \pm 15	11 \pm 14	3 \pm 3	120 \pm 120	2.5 \pm 2.3
	B	91 \pm 9	6 \pm 6	3 \pm 5	140 \pm 210	2.0 \pm 1.6
Weekend Periods^b						
Sleep	G	98 \pm 9	2 \pm 8	0.2 \pm 0.4	8 \pm 18	0.2 \pm 0.4
	B	98 \pm 5	1 \pm 5	0.2 \pm 0.4	11 \pm 17	0.2 \pm 0.3
Early morning	G	84 \pm 13	11 \pm 8	5 \pm 5	240 \pm 250	3.7 \pm 2.3
	B	81 \pm 15	12 \pm 10	7 \pm 6	320 \pm 330	3.3 \pm 2.1
Morning	G	56 \pm 16	29 \pm 12	15 \pm 7	710 \pm 370	7.3 \pm 2.3
	B	56 \pm 16	25 \pm 10	19 \pm 10	930 \pm 540	5.8 \pm 2.3

Afternoon	G	57 ± 14	28 ± 10	16 ± 7	760 ± 370	7.1 ± 2.2
	B	57 ± 12	24 ± 9	20 ± 8	970 ± 440	6.2 ± 1.9
Late afternoon	G	67 ± 11	22 ± 8	11 ± 6	530 ± 300	6.6 ± 2.1
	B	70 ± 12	18 ± 8	11 ± 6	500 ± 310	5.7 ± 1.9
Evening	G	89 ± 10	8 ± 8	3 ± 3	140 ± 140	2.8 ± 2.3
	B	88 ± 13	8 ± 10	3 ± 6	150 ± 190	2.5 ± 2.2

^aBefore school, 06:00-07:59; Morning travel, 08:00-08:59; School, 09:00-14:59; Afternoon travel, 15:00-15:59; After school, 16:00-19:59; Evening, 20:00-21:59.

^bEarly morning, 06:00-8:59; Morning, 09:00-11:59; Afternoon, 12:00-15:59; Late afternoon, 16:00-19:59; Evening, 20:00-21:59.

Uncertainty (90% confidence limits) for comparisons of different weekday periods with school period was $\sim\pm 4.5\%$.

Table A.3. shows overall means and standard deviations as well as values from the reliability analysis for sitting/lying, standing, stepping, step counts and sit-to-stand counts in girls and boys during week and weekend days. There were moderate differences between girls and boys in time spent stepping favoring the boys during weekdays and sit-to-stand transitions favoring the girls during the weekend. All other comparisons produced small (favoring the boys) to unclear results; in particular, the boy-girl comparison for time spent sitting/lying was unclear, although the observed difference was trivial. During weekdays, typical errors for girls were almost double than those of boys for time spent sitting/lying and standing, with the largest typical error in time spent sitting/lying in girls. On the weekends for time spent sitting/lying and standing boys showed higher typical error values than girls. ICC for time spent sitting/lying, standing and stepping ranged from 0.40 to 0.64 during weekdays and from 0.36 to 0.69 during weekend days. Typical error, SD, and ICC represent values between Week 1 (average of each day was averaged for the week), and Week 2.

All the differences in activity between weekdays and weekend days in Table 3 were clear (confidence limits not shown) and were typically small, with more sitting/lying and less standing and stepping in the weekends. There were moderate differences in sit-to-stand counts in boys, with less counts on the weekend. Week-to-weekend ICC values showed slightly less consistency but followed similar trend with week-to-week ICC values (data not shown).

Table A.3. Daily sitting, standing, stepping, step counts and sit-to-stand counts over 24-h for weekday and weekend days for girls (G) and boys (B) in Auckland, New Zealand. Data are mean \pm SD, girl-boy comparison with $\pm 90\%$ confidence limits (CL), typical error, and intraclass correlation coefficient (ICC).

			Δ mean (G-B), \pm CL;	Typical	
		Mean \pm SD	inference	error ^a	ICC ^b
Weekday					
Sitting (%) ^c	G	77.5 \pm 4.6	0.3, \pm 1.9;	3.4	0.45
	B	77.2 \pm 4.0	unclear ^d	2.6	0.58
Standing (%)	G	14.4 \pm 3.6	1.1, \pm 1.4;	2.3	0.59
	B	13.3 \pm 2.6	Small	1.5	0.64
Stepping (%)	G	8.1 \pm 1.7	-1.3, \pm 0.9;	1.3	0.45
	B	9.4 \pm 2.1	moderate	1.4	0.55
Step counts (h ⁻¹)	G	399 \pm 85	-55, \pm 47;	65	0.40
	B	454 \pm 108	small	77	0.51
Sit-to-stand counts (h ⁻¹)	G	4.1 \pm 0.9	0.2, \pm 0.4;	0.4	0.79
	B	3.9 \pm 0.7	unclear	0.5	0.48
Weekend					
Sitting (%)	G	78.9 \pm 4.4	0.5, \pm 2.3;	2.9	0.58
	B	78.4 \pm 5.6	unclear	4.3	0.40
Standing (%)	G	13.8 \pm 3.0	0.9, \pm 1.6;	1.7	0.69
	B	12.9 \pm 4.1	small	3.3	0.36
Stepping (%)	G	7.3 \pm 2.5	-1.3, \pm 1.3;	1.8	0.46
	B	8.6 \pm 2.9	small	1.9	0.55
Step counts (h ⁻¹)	G	347 \pm 128	-66, \pm 68;	107	0.31
	B	413 \pm 154	small	105	0.53
Sit-to-stand counts (h ⁻¹)	G	4.0 \pm 0.9	0.6, \pm 0.4;	0.7	0.31
	B	3.4 \pm 0.8	moderate	0.7	0.25

^aWeek-to-week within-subject standard deviation; uncertainty (90% confidence limits) for all estimates $\sim \times/\div 1.30$.

^bWeek-to-week intraclass correlation coefficient; uncertainty for all estimates $\sim \pm 0.20$.

^cPercent of 24 h spent in the given activity.

^dUnclear indicate values where CL span substantial positive and negative values.

Discussion

ActivPAL data revealed that children spend the majority of time during waking hours sitting/lying, with a small increase in weekends compared with weekdays. The results are in agreement with a recent study by Steele ((321)) where authors reported that children spend 60 - 80% of hourly time, both at weekdays and on weekends in sedentary activities. Sedentary behavior has often been measured objectively with accelerometry, but researchers have been unable to differentiate between sitting/lying and standing. The inclusion of an inclinometer in the ActivPAL accelerometer allows for such differentiation. The ActivPAL was used to quantify sitting/lying, standing, stepping and sit-to-stand for periods of daily living for the first time in children. Reliability data for sample size estimation when designing intervention studies to reduce sitting/lying time in children were also provided.

Overall, children spent $\sim 65\%$ (9 h) of their waking hours (14 h-day) sitting/lying. Matthews (314), Mitchell (322) and Sardinha (323) using the Actigraph accelerometer reported 6 h, 7.3 h and 5.3 h of sedentary time (13-14 h-day) in American, British and Portuguese children respectively. These figures are lower than the reported results in the current study. The disparity may stem from differences in the duration of monitoring, cultural or environmental. Interestingly, in the current study, girls and boys had similar levels of sitting/lying, but girls stood more while boys stepped more.

In the analysis of activity during meaningful periods of the day, boys and girls spent the most amount of time sitting/lying in the before-school and after-school periods. The least amount of sitting/lying was observed during the morning-travel period, which probably indicates engagement with active transport. Sitting times during school and afternoon-travel periods were similar, but sitting progressively increased for the remainder of the day. On the weekends, children accumulated the highest amount of sitting/lying in the early-morning period, presumably indicating that they took longer to rise in the morning or spent time engaging in screen-related activities. The least amount of sitting/lying in the weekend was observed in the morning and afternoon periods.

When we compared the school period with the other periods, it was evident that weekday morning and afternoon travel periods contributed less sitting/lying, and greater time in standing and walking. All other periods contributed more sitting/lying, less standing and less walking. In agreement with other studies ((324)), the school period plays a critical role in the daily activity levels in children. The breakdown of the day into meaningful periods provided a more detailed picture of the patterning of sedentary behavior in children.

Accelerometer studies report conflicting results about periods when children are most active. Nilsson et al. ((325)) showed that the average time spent in moderate/vigorous physical activity (MVPA) was higher on weekdays compared to weekend days. Similarly, Gavarry et al. ((326)) showed that time engaged in MVPA was greater on school days compared to free days. On the other hand, others ((321, 327)) reported that children exhibited higher levels of MVPA or vigorous physical activity on weekends. Still others have found no substantial differences between weekday and weekend days ((328)) and for either gender ((329)). Pedometer studies generally show that children accumulate less steps on weekend days compared to weekdays ((330, 331)). Locality-specific differences in lifestyle may account for at least some of the differences between studies, but it is less clear why pedometer studies appear to be more consistent in showing that weekend days are less active. The current study clearly shows less activity on weekend days in terms of less step counts and less time spent stepping.

The findings from this study can be used to estimate sample size for future interventions aimed at changing sedentary behavior in children. The crucial issue in sample-size estimation with interventions is the magnitude of the smallest important effect in relation to the typical error. When the smallest effect and the error are similar in magnitude, a parallel-groups controlled trial with measurements pre- and post-intervention requires only ~13 subjects in each group for acceptably low risk of harm when the finding is at least a possible benefit ((332)). In the present study, the typical error for the weekly average sitting/lying time was ~3.5%, or ~50 min per day, so an intervention aimed at reducing sedentary time by this amount can be carried out with ~26 children. If the aim is to reduce sedentary time by at least half an hour per day, the sample size will need to be four times larger; similarly, a comparison of changes in activity in boys vs girls will also need four times as many subjects ((332)). It is important to understand that each child will need to be monitored continuously for a

week; activity monitored for fewer days or for only specific periods during the day would be less reliable and would therefore entail more children in the study. The uncertainty in our estimates of typical error also means that the necessary sample size could be substantially larger or smaller. Given all these uncertainties, we advise researchers to adopt the strategy of intervening sequentially with groups of at least 20-25 subjects until the outcome is clear.

The ICC values observed in this study were moderate. On the basis of this and other studies ((321, 331)), interventions for reduction of sedentary behavior and increase in physical activity could focus on most weekday and weekend periods. A comprehensive approach may be more effective than concentrating on specific periods during the day.

Notwithstanding the novelty (measuring sitting/lying and standing in children) and rigor of this study (random sampling stratified by SES, geographical location and school roll, 14 days of data collection, 24/7 wear time, and sampling over a full school year), there were limitations. The study was conducted in one city in a relatively small sample; it needs to be repeated in other cities and other countries. In this study there was a focus on the senior grades of elementary school children only; other grades, especially beyond elementary school, need to be included. While the ActivPAL accelerometer has been used in studies with adult participants with high validity in sitting/lying, standing and stepping, and high reliability in stepping ((333, 334)), no study has determined the validity of these monitors with children. From the authors own current unpublished work (paper under review), high validity as that in studies with adults was observed. Even though it was not the purpose of this study to investigate the types of sedentary behaviors, these were not assessed and can only speculate on the kind of behaviors children were undertaking during sitting/lying.

In conclusion, the ActivPAL monitor provided the opportunity to differentiate between sitting/lying and standing. The device will be useful for investigating factors affecting habitual sitting/lying, standing and walking patterns and for studying the impact of sedentary behavior on health, especially in overweight children.

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