Patterns of sedentary behaviour and cardiovascular health in children

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Patterns of sedentary behaviour and cardiovascular health in children

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Abstract

Cardiovascular disease (CVD) risk factors (overweight and obesity, elevated blood pressure and adverse lipid profiles) are increasingly evident in children and sedentary behaviour may be an important contributing factor. However, this is inconclusive in children as much of the evidence to date is based on self- and proxy-report measures of television viewing (TV) or total screen time. These measures do not inform the unique contribution of specific types of screen-based behaviours (SBBs), such as computer use and electronic games (e-games) to children's CVD health and total screen time may not be indicative of children's overall sedentary time. Furthermore, evidence is emerging to suggest that in addition to total sedentary time, patterns of accumulation of sedentary time (breaks in and bouts of sedentary time), may be important to cardiovascular health. Consequently, objective measures are needed to examine the association between total sedentary time and patterns of accumulation of sedentary time with CVD risk factors in children.

The overarching aim of this thesis is to examine the prevalence and patterns of children's sedentary behaviour and associations with CVD risk factors. It addresses gaps in the literature concerning how much time children spend in three key leisure time SBBs (TV viewing, computer use and e-games), when children are sedentary, and how that time is accumulated. Furthermore, this thesis aims to provide a greater depth of information concerning the association between specific types of SBBs, objectively-measured prevalence and patterns of

sedentary behaviour and CVD risk factors in children. As moderate- to vigorous-intensity physical activity (MVPA) and diet energy density are established determinants of CVD risk, this thesis examines these associations independent of MVPA and diet energy density.

The first chapters describe the prevalence and patterns of children's subjectively- and objectively-measured sedentary behaviour. The participants were 7-10 year old children participating in the Transform-Us! cluster randomised controlled trial in Melbourne, Australia. Baseline data were drawn from parental-proxy reported time spent in different SBBs (n=433), children's ActiGraph measured prevalence and patterns (time of day, breaks and bouts) of sedentary time (n=405), and children's *activ*PAL™ measured prevalence and patterns of sitting time (n=171). Additional ActiGraph and CVD risk factors data were drawn from the control group of children participating in the LifeStyle of Our Kids (LOOK) study (n=209); a 4-year longitudinal quasi-experimental study.

A high percentage of children exceeded screen time guidelines on weekdays (boys, 44%, girls 40%) and weekend days (boys 82%, girls 74%), which state children should spend no more than 2-hours per day in electronic media (TV viewing, e-games and computer use). TV viewing comprised the greatest percentage of total screen time on weekdays (boys 69%, girls 76%) and weekend days (boys 60%, girls 67%). Computer use comprised the smallest proportion of total screen time and was similar for boys and girls on weekdays (13.5 and 13.2% respectively) and weekend days (12.3 and 15.1% respectively). However, the contribution of e-games to total screen time was higher in boys compared to girls on weekdays (boys 18%, girls 11%: $p<0.001$) and weekend days (boys 28%, girls

17%: $p<0.001$). Results from ActiGraph and *activ*PAL^{TM} analysis found that children spent approximately 60% of their day sedentary/sitting and this was similar for a total weekday and weekend day. However, the temporal pattern of accumulation across weekdays compared to weekend days was markedly different with clear peaks in sedentary/sitting time on weekdays during class periods and the afternoon and evening compared to a consistently high level of sedentary/sitting time (~60%) across all weekend periods. The breaks and bouts analysis found the frequency of bouts was highest for the shorter bouts lengths of 2-5 and 5-10 minutes. Consistent with this finding, the frequency of children's breaks was also high. However, the frequency of breaks was higher as measured by the ActiGraph on both weekdays and weekend days (Frq=247 and 267, respectively) in comparison to the *activ*PAL^{TM} (Frq=59 and 58, respectively). This discrepancy between devices suggests the ActiGraph and the *activ*PAL are measuring different aspects of children's sedentary patterns.

It is not known whether time spent in screen-based pursuits ot total screen time is an indicator of overall sedentary/sitting time or patterns of sedentary and sitting time. Therefore, in addition to assessing the prevalence and patterns of sedentary behaviour, this thesis examined the association between time spent in specific SBBs and total screen time and objectively measured sedentary and sitting time prevalence and patterns. Baseline data were drawn from participants in the Transform-Us! study with parental-proxy reported time spent in specific SBBs and valid AciGraph or *activ*PAL^{TM} data (n=289 and n=121, respectively). There were no significant differences in the amount of total time spent sedentary or sitting in children who met screen time guidelines compared to children who exceeded screen time guidelines. However, among all children (boys and girls combined), there was a seven minute increase in overall sedentary time for every one hour increase in e-games usage on weekend days ($p<0.05$). In addition, among girls, each additional hour spent in TV viewing was significantly and positively associated with a 16 minute increase in sitting time on weekend days. Furthermore, among girls, weekend day TV viewing time was associated with a higher frequency of sitting bouts longer than 15 minutes ($p<0.01$) and weekend day computer use was associated with a higher frequency of 5-10 minute sitting bouts ($p<0.05$).

Lastly, this thesis aimed to examine the associations between time spent in specific SBBs, total sedentary and sitting time, and breaks in and bouts of sedentary and sitting time with CVD risk factors (body mas index (BMI), waist circumference (WC), systolic blood pressure (SBP), diastolic blood pressure (DBP), high density lipoprotein cholesterol (HDL-C), low density lipoprotein cholesterol (LDL-C), triglycerides (TG), and a clustered CVD risk score). Data were drawn from participants in the Transform-Us! study who had valid parental-proxy-reported time spent in TV viewing, e-games and computer use, sedentary time and MVPA (ActiGraph data), diet energy density, and at least one CVD risk factor measure (n=264). Participants in the LOOK study who had valid ActiGraph data and at least one CVD risk factor measure were pooled with the Transform-Us! data, resulting in a total sample of 390 children aged 7-12 years. A subsample of children from the Transform-Us! study with valid *activ*PAL^{TM} data and a minimum of one CVD risk factor measure were included in the analysis of the association between sitting time prevalence and patterns with CVD risk factors (n=107).

Few significant associations were observed between sedentary behaviours and CVD risk factors, with most of these observations seen for time spent in TV viewing and *activ*PAL^{TM} measured sitting time prevalence and patterns irrespective of controlling for MVPA and diet. TV viewing was positively associated with WC and SBP, and e-games with LDL-C, after adjusting for socioeconomic status (SES), MVPA and diet energy density. There were no associations between time spent using a computer and CVD risk factors. Total time spent sitting was not associated with any of the CVD risk factors examined; although the frequency of sit-to-stand transitions and 5-10 and 10-15 minute bouts was significantly and beneficially associated with SBP. Conversely, a higher frequency of 10-15 minute bouts was significantly, yet detrimentally associated with TG levels. ActiGraph assessed sedentary time and patterns of sedentary time were not associated with CVD risk factors.

Overall, the findings from this thesis support widespread concern that children are engaging in high volumes of subjectively- and objectively-determined sedentary behaviour, and strategies to reduce sustained sitting/sedentary time are important early in life. The school day was found to dictate sedentary patterns, yet without this structure children spent consistently high levels of sedentary time across all periods of the weekend day. This has important public health implications, as on the one hand the structure of class time represents an opportunity to target children's sedentary behaviour, yet interventions are also needed during discretionary leisure time. Time spent in TV viewing, e-games and computer use and total screen time were not associated with objectively- measured sedentary or sitting time prevalence or patterns. Therefore, it appears that these measures are assessing different aspects of sedentary behaviour and time spent in different SBBs should be treated as a contextual measure of what children are doing when they are sedentary rather than a proxy for overall sedentary time. Emerging but weak evidence of some associations between SBBs, sitting patterns and CVD risk factors suggests longitudinal studies, with a longer behavioural and pathological trajectory, as well as intervention studies to determine dose response relationships for sedentary bout lengths, may be needed. In addition, measures with greater sensitivity and specificity to detect early pathological change, such as inflammatory markers, retinal analysis and endothelial dysfunction, may be important for future sedentary behaviour and CVD research in young populations.

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She believed she could so she did

Table of Contents

List of Tables

List of Figures

List of Appendices

List of Abbreviations

Abbreviation	Meaning
BMI	Body mass index
CHMS	Canadian Health Measures Survey
CVD	Cardiovascular disease
DBP	Diastolic blood pressure
DXA	Dual energy x-ray absorptiometry
EYHS	European Youth Heart Study
HDL-C	High density lipoprotein cholesterol
LDL-C	Low density lipoprotein cholesterol
LOOK	Lifestyles of our Kids study
LPL	Lipoprotein lipase
MET	Metabolic equivalent
MVPA	Moderate- to vigorous-intensity physical activity
NHANES	National health and Nutrition Examination Survey
SAPAC	Self-Administered Physical Activity Checklist
SBBs	Screen based behaviours
SBP	Systolic blood pressure
SES	Socioeconomic status
SPEEDY	Sport, Physical Activity and Eating Behaviour: Environmental Determinants in Young people
TV	Television
TG	Triglycerides
WC	Waist circumference

Chapter 1
Thesis Overview

The prevalence of childhood obesity has risen to be as high as 25 - 30% in many industrialised countries (Australian Bureau of Statistics 2013b; Ryley 2013; Skinner & Skelton 2014) and there is evidence that other cardiovascular disease (CVD) risk factors, such as adverse lipid profiles and elevated blood pressure are apparent at an early age (Booth, Okely, et al. 2006; Ekelund et al. 2009; Cliff et al. 2013). Screen-based behaviours (SBBs); television viewing (TV), playing electronic games (e-games) and computer use are key children's leisure time sedentary pursuits and have been implicated in poorer health outcomes in children (Chinapaw et al. 2012; Marshall et al. 2004; Rey-Lopez et al. 2008; Tremblay, LeBlanc, Kho, et al. 2011).

Several countries have made recommendations to limit recreational screen time to no more than two hours per day (External working group under the National Board of Health 2003; National Heart Foundation of New Zealand 2004; Tammelin et al. 2007; The Department of Health 2014; The Department of Health and Children 2009; Tremblay, Leblanc, Janssen, et al. 2011). However, prevalence estimates indicate that between 40 and 80% of children are spending more than 2-hours per day engaged in screen time (Active Healthy Kids Canada 2013; Australian Bureau of Statistics 2013b; Sisson et al. 2009). While there are public health recommendations for screen time, time spent in SBBs may not reflect children's total sedentary time (Verloigne et al. 2013).

In adults, there is consistent evidence of adverse health outcomes associated with time spent being sedentary (Thorp et al. 2011) and the deleterious consequences remain after taking into account MVPA (Chau et al. 2013). However, evidence of objectively measured total sedentary time and the associations with CVD risk factors in children is equivocal (Froberg & Raustorp 2014). In addition to total sedentary time, evidence from adult studies (Dunstan, Kingwell, et al. 2012; Healy et al. 2011; Healy, Wijndaele, et al. 2008) suggests patterns of sedentary behaviour (i.e. bouts of and breaks in sedentary time), may also be important to cardiovascular health. Associations between these patterns and children's CVD risk factors are not well understood.

The overarching aims of this thesis were therefore to examine the prevalence and patterns of children's SBBs and objectively measured sedentary time, and the associations with CVD risk factors. Secondly, this thesis aimed to examine the association between children's time spent in SBBs, total sedentary time and patterns of sedentary time.

Chapters 2 and 3 provide the background to the studies presented in this thesis; a review of the literature and the methods of the Transform-Us! and Lifestyle of Our Kids (LOOK) studies respectively.

Chapters 4 to 6 describe the prevalence and patterns of sedentary behaviour. Chapter 4 describes boys' and girls' time spent in different SBBs and total screen time on weekdays and weekend days. Chapter 5 describes ActiGraph measured sedentary time and breaks in and bouts of sedentary time within a total day and discrete periods of the day on weekdays and weekend days. Chapter 6 describes *activ*PAL™ determined sitting time and breaks in and bouts of sitting time within a total day and discrete periods of the day on weekdays and weekend days. Chapter 7 then examines the association of time spent in different SBBs and total screen time with objectively measured sedentary and sitting time prevalence and patterns.

In chapters 8 to 10 the three measures of sedentary behaviour (screen time, sedentary time and sitting time) are used to examine the association between these measures and key traditional CVD risk factors (adiposity, blood pressure and lipids). Much of the available evidence base of children's sedentary behaviour and CVD risk is determined from studies of total screen time or TV viewing and body mass index (BMI), and the results are inconclusive. Therefore Chapter 8 examines the association between different SBBs and CVD risk factors. As it is difficult to assess patterns of sedentary behaviour from measures of screen time, Chapter 9 utilises ActiGraph determined sedentary patterns to examine the association with CVD risk factors. Lastly, with the emerging emphasis to use objective measures of posture, Chapter 10 examines the association between *activ*PAL™ determined sitting time patterns and CVD risk factors.

Chapter 11 provides an overview of the key findings from Chapters 4 through 10 and discusses the implications for future research and interventions. An overview of the limitations and strengths of the studies is also discussed.

Chapter 2
Literature Review

2.1 Introduction

The purpose of this chapter is to provide a review of the evidence which investigates children's sedentary behaviour and CVD risk factors. Within a public health context, a high percentage of children are overweight or obese and CVD risk factors that were typically known to manifest in adulthood, such as elevated blood pressure and adverse lipid profiles, are evident in children. Sedentary behaviour is believed to be an important contributing factor. This chapter therefore begins by establishing the current state of children's health in relation to CVD risk factors. It then assesses the evidence regarding children's time spent in different SBBs (TV viewing, e-games and computer use) and total screen time as well as studies that have used accelerometers or inclinometers to describe the prevalence and patterns of sedentary behaviour in children.

TV viewing and total screen time are often considered as a proxy for children's overall time spent being sedentary, yet it is not known if these subjective measures of screen time accurately reflect total sedentary time. This chapter therefore examines the evidence base of studies that have assessed the association between screen time and objectively measured sedentary time.

Lastly this chapter investigates the evidence base of studies that have examined the association between screen time, and objectively measured prevalence of sedentary and sitting time with CVD risk factors in children. Furthermore, evidence is emerging to suggest that in addition to total sedentary time, the way in which it is accumulated (breaks in and bouts of sedentary time) may be important to cardiovascular health and public health guidelines have been updated to reflect the importance of breaking up prolonged time spent sitting. Therefore this chapter concludes by assessing the evidence base of studies that have examined the association between sedentary patterns and CVD risk factors in children.

2.2 Prevalence and trends in CVD risk factors among children

2.2.1 Overweight and obesity

Overweight and obesity has important implications for children's cardiovascular health. Children who are obese are more likely to exhibit additional CVD risk factors, such as raised blood pressure and hypertension (Bell et al. 2007; Freedman et al. 2007; Monego & Jardim 2006; Reinehr & Andler 2004; Ribeiro et al. 2003; Sinaiko et al. 2005) and adverse lipid profiles (Freedman et al. 1999; Holl et al. 2011; Reinehr & Andler 2004). A systematic review of the tracking of childhood overweight into adulthood (Singh et al. 2008) found all 25 studies included in that review, of which the majority were high quality, reported an increased risk for overweight and obese youth to become overweight adults. Furthermore, childhood and adolescent obesity has been linked with mortality during middle age and chronic disease in adulthood (Engeland et al. 2003; Gunnell et al. 1998; Must et al. 1992). This may be explained by evidence from longitudinal studies that the progression of atherosclerosis is related to the persistence of risk factors over time (Juonala et al. 2005; McMahan et al. 2007; Raitakari et al. 2003).

A recent population survey reported that the prevalence of overweight and obesity (Cole et al. 2000) in Australian children aged 8-11 years was 18% and 6% for boys and 21% and 7% for girls respectively in 2011-2012 (Australian Bureau of Statistics 2013b). While it has been suggested that the prevalence of overweight is declining (Olds et al. 2011), it is higher in comparison to population estimates reported in several industrialised countries over the past two decades (Australian Bureau of Statistics 2013b; Ryley 2013; Skinner & Skelton 2014). In Australian children aged 5-17 years the prevalence of overweight and obesity increased from 20.9% in 1995 to 24.7% in 20011-12 (Australian Bureau of Statistics 2013b). In the UK, population estimates of overweight and obesity (Stamatakis 2003) increased from 24% among 2-15 year old boys and 26% among girls in 1995 to 31% in boys and 28% in girls in 2012 (Ryley 2013). Population estimates of 6-11 year olds from the National Health and Nutrition Examination Survey (NHANES) in the United States reported an increase in obesity ($\geq 95^{th}$ percentile) among girls from 19.4% in 1999-2000 to 28.4% in 2011-2012. Among boys the prevalence of obesity increased from 20.3% in 1999-2000 to 26.2% in 2011-2012 (Skinner & Skelton 2014).

2.2.2 Elevated blood pressure and hypertension

Among adults, elevated blood pressure is an established risk factor for CVD (Stanner 2005). Evidence of left ventricular hypertrophy (Hanevold et al. 2004; Litwin et al. 2006; Sorof et al. 2003) (increased thickness of the hearts main pumping chamber) and arterial wall thickening (Davis et al. 2001; Litwin et al. 2006; Sorof et al. 2003) has been identified in children and adolescents with elevated blood pressure or hypertension. Furthermore, prospective studies have found that children with high blood pressure are more likely to develop hypertension in adolescence and adulthood compared to children with normal levels of blood pressure (Bao et al. 1995; Davis et al. 2001; Juonala et al. 2005; Li et al. 2009).

Population data are not available to examine the trend of elevated blood pressure over previous years in children. However, a prevalence study of CVD risk factors in European youth (10 and 15 years) reported the prevalence of elevated blood pressure (SBP and/or DBP $\geq 95^{th}$ percentile) to be 6% among boys and 2% among girls (Ekelund et al. 2009). A Canadian study of 3-18 year olds reported a similar prevalence of elevated blood pressure (SBP and/or DBP $\geq 95^{th}$ percentile) to Europe of 3.6% (Hansen, Gunn & Kaelber 2007). Among US adolescents (aged 12-19 years), a study using NHANES 2001-2006 data reported 6.9% had elevated blood pressure (SBP and/or DBP $\geq 90^{th}$ percentile) (Johnson et al. 2009). In Australia, higher levels of elevated blood pressure have been reported by the NSW Schools Physical Activity and Nutrition Survey (SPANS) in which 20% of Grade 10 boys and 5% of Grade 10 girls had SBP and/or DBP $\geq 90^{th}$ percentile (Booth, Okely, et al. 2006). The higher prevalence rate in Australian youth is likely to reflect the lower percentile cut-point used to define elevated blood pressure, differences between ethnic groups and variation in the methodology to assess blood pressure.

2.2.3 Dyslipidaemia

Dyslipidaemia is well known as a classic risk factor for CVD (Libby, Ridker & Maseri 2002). The progression of fatty streaks to coronary-artery fibrous plaques has been shown to be associated with elevated levels of serum low density lipoprotein cholesterol (LDL-C) and triglycerides and reduced levels of high density lipoprotein cholesterol (HDL-C) (Belay, Belamarich & Racine 2004).

Prevalence data for biochemical markers of dyslipidaemia are limited in children. Among Australian children in the SPANS study, 10% of Grade 10 boys and 4% of Grade 10 girls had low levels of HDL-C (<1.03 mmol/L) (Booth et al. 2006). Among European children, 10.3% of boys and 6% of girls had low levels of HDL-C (<1.03 mmol/L) (Ekelund et al. 2009). Among US youth (aged 12-19 years), a study using NHANES 2001-2006 data reported 25.6% to have high triglyceride concentration (≥1.243 mmol/L) and 19.3% had a low HDL-C concentration (40 mg/dL) (Johnson et al. 2009). In a recent study (Cliff et al. 2013) of 126 overweight and obese children (aged 5.5-9.9 years) participating in the Hunter Illawara Kids Challenge Using Parent Support (HIKUPS) a higher percentage of children (52%) had low HDL-C (<1.03 mmol/L). Although as described in section 2.2.1, children who are overweight are more likely to have additional CVD risk factors, such as adverse lipid profiles (Holl et al. 2011), and this likely to explain the high percentage of children with low HDL-C in this cohort.

Conclusion

The manifestation of CVD risk factors, including obesity, hypertension and dyslipidaemia, have characteristically been considered adult conditions. However, evidence of these risk factors in childhood, a heightened risk trajectory associated with early life overweight and obesity, increased likelihood of additional CVD risk factors in the presence of overweight and obesity and the persistence of CVD risk factors over time necessitates greater understanding of modifiable lifestyle factors to prevent the early pathogenesis of CVD.

To date, diet (Getz & Reardon 2007) and physical activity (McMurray & Ondrak 2013) have been considered as the key modifiable lifestyle influences in CVD and are therefore typically core components in CVD prevention. Dietary factors have been studied extensively in regard to macro and micro nutrient constituents, of which some are protective and others detrimentally associated with the development of CVD risk factors (Getz & Reardon 2007). Based on evidence of increased CVD risk factors associated with foods high in saturated fat and energy dense foods as well as those containing added or high levels of salt and sugars, many industrialised countries have developed nutrition guidelines with upper limits for the consumption of these particular food types (National Health and Medical Research Council 2013; US Department of Health and Human Services 2010).

Physical activity, in particular MVPA has been established as a key modifiable lifestyle behaviour in CVD risk prevention, with higher levels associated with beneficial outcomes and insufficient levels associated with increased CVD risk factors (McMurray & Ondrak 2013). Consequently, guidelines exist for minimum weekly or daily MVPA targets across age groups in most industrialised countries as part of national strategies to increase MVPA in the population (US Department of Health and Human Services 2008; The Department of Health 2014; Canadian Society for Exercise Physiology 2011; Bull et al. 2010).

Time spent being sedentary has been increasingly recognised as a modifiable lifestyle behaviour in CVD risk prevention (Canadian Society for Exercise Physiology 2011; Dunstan, Howard, et al. 2012; The Department of Health 2014; Tremblay et al. 2010). However, in comparison to the knowledge base for dietary factors and MVPA, evidence of the relation of sedentary behaviour to CVD risk in children is in its early stages (reviewed in section 2.8). In order to ascertain the independent relevance of sedentary behaviour to CVD risk factors it is critical to control for the confounding effects of MVPA and dietary factors in epidemiological studies. Furthermore, the term ‘sedentary’ has been used widely to encompass a variety of meanings in the scientific literature (Sedentary Behaviour Reseacrh Network (SBRN) 2012). In order to build a robust evidence base of the association between sedentary behaviour and CVD risk factors, a uniform approach to the definition of ‘sedentary’ and clear communication as to the dimension of sedentary behaviour being measured is needed.

2.3 Defining sedentary behaviour

2.3.1 Sedentary behaviour

Derived from the Latin verb *sedere*, meaning “to sit”, sedentary behaviour can be conceptualised as specific pursuits that involve either sitting or lying down (Owen, Sparling et al. 2010). The compendium of energy expenditures for youth (Ridley, Ainsworth & Olds 2008) identified 46 sedentary pursuits, including reading, motorised travel, art and talking on the phone. Time spent in TV viewing, computer use and playing e-games may not represent total time spent sedentary (Verloigne et al. 2013) because children have numerous opportunities to be sedentary; however, to date they are the most commonly measured and reported in the scientific literature (Martinez-Gomez, Tucker, et al. 2009), more readily recalled (Clark et al. 2009; Craig et al. 2003), and can be related back to national screen time recommendations for monitoring purposes.

Unbroken periods of muscular inactivity that occurs while seated has been shown to have unique physiological differences in comparison to standing with little movement (Hamilton, Hamilton & Zderic 2007). Postural allocation (i.e. sitting compared to standing) may therefore be a direct indication of sedentary behaviour (Chastin & Granat 2010). Not surprisingly, in recent years there has been a growing body of opinion that sedentary behaviour should be considered as a distinct construct from light, moderate and vigorous physical activity due to independent health associations (Tremblay et al. 2010). So as not to be confused with physical inactivity, (lack of MVPA), it was initially recommended that sedentary behaviour be defined as pursuits that have a metabolic equivalent (MET) value less than 1.5 and involve a sitting or reclining position (Pate, O'Neill & Lobelo 2008). In 2012, following an expert consensus, the SBRN defined sedentary behaviour as “any waking behaviour characterised by an energy expenditure ≤1.5 METs while in a sitting or reclining posture” (SBRN 2012, p.40).

2.3.2 Screen time recommendations for youth

Time spent in SBBs is the most prevalent leisure-time sedentary pursuit in children (Martinez-Gomez, Tucker, et al. 2009). The first recommendation for screen time was released by the American Academy of Paediatrics in 2001, who quantified a maximum of total entertainment media time (TV viewing) for children to no more than 1 to 2 hours of quality programming per day (American Academy of Pediatrics Committee on Public Education 2001). In Australia the screen time recommendation for children is to limit the use of electronic media for entertainment (e.g. TV, seated e-games and computer use) to no more than two hours a day (The Department of Health 2014). Several other countries have adopted similar recommendations, including Canada (Tremblay, Leblanc, Janssen, et al. 2011), Finland (Tammelin et al. 2007), Denmark (External working group under the National Board of Health 2003), Ireland (The Department of Health and Children 2009) and New Zealand (National Heart Foundation of New Zealand 2004).

2.3.3 Sedentary behaviour guidelines – sitting time

In order to reduce health risks, the recently updated Australia's Physical Activity and Sedentary Behaviour Guidelines for 5-12 year-olds includes the recommendation to "break up prolonged periods of sitting as often as possible"(The Department of Health 2014). This is in addition to the screen time recommendation described in section 2.3.2.

These two recommendations require different measures to assess them. The assessment of compliance with screen time recommendations is typically measured subjectively by self- or proxy-reported screen time. The assessment of breaks requires objective measures which permit this to be investigated. Therefore, a combination of subjective and objective measures are needed to assess different dimensions of children's sedentary behaviour.

2.4 Measurement of sedentary behaviour

The accurate assessment of sedentary behaviour is important for monitoring prevalence and trends in different population groups including compliance with guidelines, determining dose-response associations with health indicators, identifying specific aspects of sedentary behaviour that are associated with health, and informing intervention strategy design and effectiveness (Ekelund, Tomkinson & Armstrong 2011; Sirard & Pate 2001).

A range of subjective and objective methods have been used in sedentary behaviour research to quantify sedentary time and describe what children are doing when they are sedentary (i.e. what behaviours they engage in). An overview of the methods available to measure sedentary behaviour and the main strengths and limitations associated with each is described below. The choice of which method/s to use is determined by the nature of the research question and the relative accuracy and practicality of the measurement method.

2.4.1 Subjective measurement of sedentary time

Diaries

Diaries are used to obtain a detailed account of the nature and frequency of free-living activities and can be completed by the child or the carer (Marshall & Welk 2008). Limitations involve the reliance on children's compliance and literacy, and their cognitive and recall abilities (Welk, Corbin & Dale 2000). For this reason they are not recommended in children under the age of 11 as the only source of information. Furthermore, the participant burden associated with the ongoing maintenance of recording activities reduces the feasibility of this technique in large scale studies (Marshall & Welk 2008). The burden associated with diary maintenance generally means the participant is only asked to complete the diary over a short period of time (such as one day). The ability to capture the quantity, diversity and frequency of sedentary behaviours during a representative time period is therefore compromised.

Self- and proxy-administered recall

Self- and proxy-report questionnaires are a popular option in large scale studies due to the associated low cost, convenience of administration and the ability to characterise the type and context of behaviours (Trost 2007). A key consideration in the decision to use a self- or proxy report questionnaire is the age or ability of the study population to accurately recall time spent in different activities due to the developmental changes in cognition which occur from childhood through to adolescence (Baranowski 1988). Answering a question about time spent in specific sedentary behaviours involves several complex cognitive processes; understanding the question, recalling the behaviour, estimating frequency and/or duration and providing an answer (Streiner & Norman 2008). Several studies have demonstrated children's limited cognitive ability to process the steps involved in answering a question requiring recall (Baranowski, Dworkin & Cieslik 1984; Sallis et al. 1993; Trost et al. 2000). Many researchers therefore caution the use of self-report instruments in children younger than 10 years (Trost 2007). For example, a study which assessed the reliability and validity of a seven day recall interview among fifth, eighth and eleventh year youth reported a considerable increase in the correlation for both test-retest reliability and validity from fifth year through to eleventh Year (Sallis et al. 1993). This suggests recall in young people improves with increased age.

A strategy to improve the validity of self-reports in children is to limit the recall to short time periods, such as the previous day (Welk, Corbin & Dale 2000). For example, the one day self-administered Multimedia Activity Recall for Children and Adolescents (MARCA) questionnaire, administered by computer, asks children to recall the previous day of activities in sections of five minutes or more and was developed to overcome the limited accuracy of children to recall activities over extended time frames (Ridley et al. 2006). Test-retest reliability was high (ICC= 0.88-0.94) and criterion validity was reported to be comparable to other self-report instruments (rho=0.36-0.45). However, in order to capture habitual sedentary behaviour and variation across time periods (e.g. weekdays and weekends), assessment spanning multiple days are needed (Marshall & Welk 2008). An alternative may be to utilise an interviewer who can ask prompting questions that may assist with recall. However, this is a more costly option due to the requirement of time for an interviewer to be present (Sallis 1999).

To overcome the issues associated with self-report in children, proxy-report questionnaires are more commonly used to measure the frequency and duration of children's time in sedentary pursuits. A limitation of proxy-report questionnaires, however, is the likelihood that the respondent has not observed all time spent in specific activities (Sallis & Saelens 2000). For example, if the child has a TV in their bedroom TV viewing time may be underestimated or if the TV is switched on but not being viewed the reported time spent watching TV may be overestimated (Marshall, & Welk 2008). A systematic review (Lubans et al.

2011) examined four reliability studies and three validity studies of parental proxy-reported screen time for children and concluded acceptable reliability and validity in young people (Lubans et al. 2011). Therefore, proxy-reported measures of screen time are likely to be a more accurate and appropriate measure in young children.

A strength of self- or proxy-reported behaviour is the ability of assessing engagement in specific types of sedentary behaviours. However, to assess total time spent sedentary and patterns of sedentary behaviour, e.g. breaks in sedentary time as identified in Australia's Physical Activity and Sedentary Behaviour Guidelines (The Department of Health 2014), objective measures are needed.

2.4.2 Objective measurement of sedentary time

Direct observation

Direct observation involves trained researchers observing participants and interpreting information about the duration, type, context and frequency of sedentary behaviours within specified time periods and settings (Marshall & Welk 2008). A range of studies have examined the reliability and validity of direct observation systems to assess time spent in sedentary behaviour among adolescents (McKenzie et al. 2000), young children (McKenzie et al. 1991), and primary school age children (Ridgers, Stratton & McKenzie 2010). The reliability and validity of an observation instrument, System for Observing Children's Activity and Relationships during Play (SOCARP) was examined among 99 primary school children in England (Ridgers, Stratton & McKenzie 2010). Validity of estimated energy expenditure (derived from observed time spent in different categories of activity) was assessed against mean accelerometer counts and a moderately positive significant association (r=0.67) was reported.

Direct observation is considered to have a high level of accuracy if the reliability of reporting between two researchers is high (Sallis 1999). The SOCARP study examined intra- and inter-observer reliability and reported acceptable agreement of 87% and 88% respectively for activity levels (Ridgers, Stratton & McKenzie 2010). The SOCARP observation system, however, was only assessed during school recess; therefore it's appropriateness as a measurement tool in other settings (e.g. at home) has not been established.

Practical issues limit the utility for direct observation as a measure in large scale studies. It is labour intensive, costly and has limited ability to capture all settings of children's sedentary behaviour because it mostly used in pre-determined settings such as the classroom. Consequently, direct observation tends to be used as a criterion for other measures rather than a field-based measure in large studies (Sallis 1999).

Accelerometers

Accelerometers have become an increasingly popular tool for objectively assessing children's physical activity and sedentary behaviour (Cain et al. 2013; Reilly et al. 2008). The accelerometer measures changes in velocity produced by body movement (acceleration or deceleration). Therefore, the usual positioning of the accelerometer is on the hip so that ambulatory motion such as walking is detected (Welk, Corbin & Dale 2000). Accelerometer data is date and time-stamped and therefore it is possible to define specific time frames of interest and measure the amount of time spent in different intensities of activity or sedentary time in a whole day and specific periods within the day.

Different makes of accelerometers, including the ActiGraph™, Actical™, RT3™ are commercially available and have been used in published paediatric studies to assess sedentary time (Reilly et al. 2008). The ActiGraph is the most widely used accelerometer and has the greatest strength of evidence to support its feasibility, reliability and validity in studies of school age children (Reilly et al. 2008). Several models of the ActiGraph have been used in pediatric studies of physical activity and sedentary behaviour; the 7164, GT1M and GT3X, GT3X+ and wGT3X+. The progression of the different models reflects updates that have improved the functionality of the accelerometer, such as being lighter in weight, having greater battery life, the capacity to collect data in raw format and apply shorter epochs as memory capacity has increased significantly. The most widely used ActiGraph models in published research of sedentary behaviour to date are the 7164, GT1M and GT3X. In these earlier models, accelerations produce an electrical signal which is converted to produce a quantifiable digital measure of movement, known as counts (Sirard & Pate 2001). Counts are recorded in pre-determined epochs of time ranging from one second to several minutes (Rowlands 2007). A count can be used as a raw number to indicate level of movement used to estimate METs or energy expenditure (Trost 2007). More recent models of the ActiGraph, such as the GT3X+ and wGT3X+, collect raw data, which allows for the determination of epoch length post data collection. This was not possible using the monitor versions GT1M and GT3X in LOOK and

Transform Us!; however, these were the most up to date models available at the time of data collection.

Evidence of superiority in the validity and reliability of one make/model of accelerometer compared to another is equivocal (Trost,McIver & Pate 2005). As such, factors such as cost, monitor size, product reliability, memory capacity, technical issues and comparability with other studies influence the choice of which model to use (Trost, McIver & Pate 2005). A review of studies that measured the reproducibility, feasibility and reliability of accelerometers reported the ActiGraph to have good reproducibility and validity (De Vries et al. 2009). The correlation between activity counts and the criterion measure was moderate to high (r = 0.52 - 0.77) (De Vries et al. 2009). Furthermore, a recent study of the three different generations of the ActiGraph (GT1M, GT3X and GT3X+) reported strong agreement between the models for vertical axis counts, vector magnitude counts and time spent in moderate physical activity (MPA) (Robusto & Trost 2012). That study concluded it was acceptable for different models of the ActiGraph to be used within any given study which is likely to increase the availability of accelerometers in studies where more than one model is available.

The accelerometer measures movement; therefore, a cut-point is applied to determine sedentary time as the time spent below a defined intensity threshold (Lubans et al. 2011). Studies of sedentary behaviour in young people have applied a range of intensity thresholds; for example, 100 (Matthews et al. 2008), 200 (Mitchell et al. 2009), 500 (Ekelund et al. 2007), 800 (Riddoch et al. 2007) and 1100 counts per minute (cpm) (Guinhouya et al. 2007). In addition to the time stamped ability of accelerometers, the application of a threshold for sedentary time enables sedentary breaks and bouts to be assessed because a deviation above that threshold determines a break in sedentary time or the end of a sedentary bout.

The ActiGraph accelerometer has been validated for sedentary time against cut points of 100 cpm (Evenson et al. 2006; Ridgers et al. 2012; Treuth et al. 2004) and 800 cpm (Puyau et al. 2002) in school-age children. Two calibration studies, one involving 74 adolescent females aged 13-14 years (Treuth et al. 2004) and one of 33 children aged 5-8 years (Evenson et al. 2006) measured oxygen consumption during activities that involved sitting or lying quietly. Maximum sensitivity and specificity was achieved at ≤100 cpm. Furthermore, a recent free-living study involving 48 children aged 8-12 years examined the agreement between ActiGraph accelerometer cut points ranging from 50-850 cpm against sitting time as measured by the *activ*PAL™ inclinometer (Ridgers et al. 2012). Receiver operator characteristics (ROC) analyses obtained acceptable sensitivity (76.7%) and specificity (67.8%) at a cut-point of 96 cpm (AUC=0.75) for sitting time during school hours. Conversely, a study of 26 young people aged 6-16 years reported a threshold count of <800 cpm for sedentary activities (Puyau et al. 2002). Threshold counts were derived by computing activity energy expenditure (energy expenditure – resting metabolic rate) regressed against counts. That study (Puyau et al. 2002), however, may have overestimated the energy expenditure of sedentary activities and the associated counts because the activities included playing on a floor mat with toys, which may involve intensities greater than those associated with sedentary behaviours.

Several considerations are important in the use of accelerometers. The interpretation of accelerometer output is influenced by the cut-points applied (Ekelund, Tomkinson & Armstrong 2011). Studies of sedentary time have utilised cut-points equivalent of up to 2 METs or a cut-point using cpm ranging from zero to 100-1100 cpm (Reilly et al. 2003) making comparability between studies difficult (Ekelund, Tomkinson & Armstrong 2011). Misclassification of sedentary time is likely to occur when cut-points above 100 cpm, are applied (Ekelund, Tomkinson & Armstrong 2011). Accelerometers can only determine whether the wearer was not moving very much and no information on whether this time was accumulated when the individual was sitting, lying down or standing with little movement can be obtained (Tremblay et al. 2010). Further, accelerometers do not provide contextual information concerning what children are doing when they are sedentary.

Inclinometers

A recent development in sedentary behaviour research is inclinometers, such as the *activ*PAL™. This device is small, unobtrusive and is worn on an elasticated band around the mid-thigh. It distinguishes sitting time due to the inclusion of an inclinometer, which can determine whether the limb (thigh) of the wearer is vertical (i.e. standing) or horizontal (i.e. sitting or lying down) (Grant et al. 2006). This ability is due to the capacity to measure tilt angle such that when it is attached to the anterior of the upper leg it can interpret femur angle (Schofield, Quigley & Brown 2009). Since the *activ*PAL™ can detect time spent sitting, issues associated with the reliance on cut points as identified with hip-mounted accelerometers may be overcome.

As with accelerometers, the *activ*PAL™ is time-stamped and therefore it is possible to define specific time frames of interest and measure the amount of time spent sitting within a whole day and specific periods within the day. Therefore, information on high and low periods of sitting time can be identified which may be particularly useful in determining critical windows of opportunity within which to maximise the effectiveness of strategies to reduce children's sitting time. In addition to the time stamped ability of the *activ*PAL™, the direct measurement of sitting time enables sit-to-stand transitions and bouts of sitting time to be assessed because a change in posture from sitting/lying to standing stepping determines an interruption to sitting time or the end of a sitting bout.

Adult validation studies have reported the *activ*PAL™ to have excellent reliability and validity of posture and motion during everyday activities (Grant et al. 2006; Ryan et al. 2008). A recent validation study found the *activ*PAL™ to be a more precise measure of sitting time compared to the ActiGraph (Kozey-Keadle et al. 2011). Twenty office workers were observed for two periods of six hours whilst wearing an *activ*PAL™ and ActiGraph accelerometer (Kozey-Keadle et al. 2011). Validity was assessed using a range of accelerometer cut-points from 50 to 250 cpm and *activ*PAL™ output of time spent sitting/lying against direct observation of sitting/lying and non-sedentary behaviour. The correlation between the *activ*PAL and direct observation of sitting/lying time was considerably higher in comparison to that of the ActiGraph utilising ≤ 100 cpm threshold (R^2 = 0.94 and R^2 = 0.39 respectively).

In conclusion, depending on the threshold applied accelerometers may over- or under-estimate sitting time (Kozey-Keadle et al. 2011; Ridgers et al. 2012). The measurement of posture (i.e. sitting time) has been proposed as a more appropriate measure of sedentary time (Owen, Healy et al. 2010; Bassett, Freedson & Kozey 2010). However, contextual information about what children are doing when they are sedentary is not assessed with objective measures and therefore it is recommended that a combination of objective and subjective measures be used (Lubans et al. 2011). Whilst objective data informs opportunities to intervene (e.g. after school hours) reported time spent in sedentary behaviours provides information about which behaviours to target. On the basis of these important considerations this doctoral thesis will utilise data from objectively measured sedentary (accelerometers) and sitting (inclinometers) time and proxy-reported screen time.

2.5 Prevalence of sedentary behaviour

2.5.1 Prevalence of screen-based behaviours

As discussed in section 2.3.2, several countries have implemented recommendations for screen time for entertainment purposes to be limited to no more than 2-hours per day. The prevalence of screen time is often reported in terms of the percentage of people exceeding screen time recommendations. Results from population estimates suggest considerable variability in the levels of children's screen time. In Australia for example, 71% of 5-17 year olds exceed the recommendation of "no more than 120 minutes of screen-based entertainment" (Australian Bureau of Statistics 2013a) per day on each of the previous seven days of recall. In the US National Health and Nutrition Examination Survey (NHANES), parents of children aged 6-11 years proxy-reported the average daily screen time (TV and computer use) over the previous

30 days (Sisson et al. 2009). Forty-seven percent of children (6-11 years) were reported to exceed screen time recommendations. Whilst this is a lower percentage than Australia, time spent playing e-games was not included in the measure of total screen time (Sisson et al. 2009) and the estimates from Australia encompassed an older age range of children who may engage in higher levels of screen time.

In comparison to Australia and the US, a lower percentage of children were reported to exceed screen time recommendations in the UK-based Avon Longitudinal Study of Parents and Children (ALSPAC) in which participants were asked about how much time they usually spend watching TV (Mitchell et al. 2009). Thirty-one percent of boys and 29% of girls were reported to exceed screen time recommendations; however, only TV viewing was measured. It is likely that the variation in the percentage of children reported as exceeding screen time recommendations reflects variability in the inclusion of different SBBs as a measure of screen time (e.g. TV viewing only or TV viewing and computer use).

2.5.2 Prevalence of objectively measured sedentary and sitting time

Sedentary time

High levels of sedentary time have been reported in several large population studies (Matthews et al. 2008; Nilsson, Anderssen & Andersen et al. 2009; Steele et al. 2010). Sedentary time (≤100 cpm) as measured in the National Health and Nutrition Examination Survey (NHANES) 2003-2004 (Matthews et al. 2008), the UK Sport, Physical Activity and Eating Behaviour (SPEEDY) (Steele et al. 2010) and the European Youth Heart Study (EYHS) (Nilsson, Anderssen & Andersen

2009) ranged from 4.0 hours – 7.0 hours per day. The International Children's Acceleromtery Database (ICAD), which pooled data on objectively measured physical activity and sedentary time, has reported time spent being sedentary among youth (aged 3-18 years) in 14 countries (Ekelund et al. 2012). Based on a threshold of ≤100 cpm, the lowest daily level of sedentary time reported was in the MAGIC study in Scotland in which children spent 192 minutes per day being sedentary. However, the age group was 4-5 year old children. The highest level of sedentary time was reported in the Pelotas study of 13-14 year olds in Brazil who spent 491 minutes per day sedentary. In eight of the studies time spent sedentary was between 325 and 378 minutes per day.

Among 9-year old children from four European countries participating in the EYHS, sedentary time was assessed on weekdays and weekend days (Nilsson, Anderssen & Andersen et al. 2009). Among boys, sedentary time ranged from 4.6 hours 5.2 hours/ day on weekdays and between 4-hours and 5-hours/day on weekend days. In girl's, sedentary time ranged from 5.1 hours/day to 5.7 hours/day on weekdays and on weekend days from 4.3 to 4.7 hours/day. In a UK based study, (SPEEDY), sedentary time was assessed in 1568 children (9-10 years) on weekdays and weekend days (Steele et al. 2010). Children in that study spent between 4 hours sedentary on a weekday and 7-hours on a weekend day sedentary. A study of nearly 1000 children in the US (Matthews et al. 2008) aged 6-11 years from NHANES 2003-2004, reported boys spent 6.0 hours/day sedentary and girls spent 6.1 hours/day sedentary. The higher average level of sedentary time reported in that study is likely to report the inclusion of a weekend day in the calculation of an overall daily average.

These levels of sedentary time support widespread concern that children are engaging in high amounts of sedentary time. However, due to the reliance on a cut point to determine sedentary time it is not possible to determine if these reported levels reflect sitting time.

Sitting time

To the best of the candidate's knowledge, information on children's total sitting from population based studies are not available. However, one study in children (Hinckson et al. 2013) and two in adolescent females (Dowd et al. 2012; Harrington et al. 2011) have reported estimates of total sitting time in cross-sectional studies. In a sample of 44 females, aged 15-17 years from Ireland 18.9 hours were spent sitting/lying within a 24-hour day and 9.2 hours during waking hours (Dowd et al. 2012). In a larger sample of adolescent females (n=102) aged 15-18 years from Ireland approximately 18.9 hours were spent sitting/lying on a weekday and a weekend day (Harrington et al. 2011). However, that study did not differentiate between sleep time and waking hours so it is not possible to determine the amount of sitting time that took place during waking hours. Among a sample of 56 children aged 9-10 years in New Zealand (Hinckson et al. 2013), equally high rates of sitting time were reported on weekdays (77.5%) and weekend days (78.9%). An important limitation however, is the monitor was worn continuously for 24 hours and sitting time during waking hours was therefore not specified.

2.6 Patterns of objectively measured sedentary and sitting time

As previously identified in section 2.4.2, due to the date and time stamped ability of the ActiGraph and the *activ*PAL™ it is possible to define specific periods of interest and assess sedentary/sitting time and breaks in and bouts of sedentary/sitting time across the day.

2.6.1 Current definitions of patterns of objectively measured sedentary time

In this doctoral thesis 'patterns of sedentary time' includes temporal patterns of sedentary time, bouts of uninterrupted sedentary time and breaks in sedentary time. These are described below.

Defining temporal patterns of sedentary behaviour

A temporal pattern of sedentary time is the accumulation of sedentary time across pre-defined periods of the day. As described in section 2.5.2, children are spending up to seven hours of their waking day sedentary. In order to reduce overall sedentary time it is important to investigate when periods of high engagement in sedentary time is occurring so as to inform critical windows of opportunity within which to maximise health promotion strategies that aim to reduce sedentary time.

Few studies have examined objectively-measured temporal patterns of accelerometer-determined sedentary time (Bailey et al. 2012; Guinhouya et al. 2007; Steele et al. 2010) and inclinometer-determined sitting time with the *activ*PAL™ (Harrington et al. 2011) in youth. Studies of accelerometer-based temporal patterns have used different time frames to define periods of the day including hour-by-hour patterns and school versus non-school time (Steele et al. 2010), periods of the school day (i.e. class time and break time) (Bailey et al. 2012) and different periods of the waking day (morning, noon, afternoon and evening) (Guinhouya et al. 2007). Studies of inclinometer determined sitting temporal patterns are limited to the examination of school hours compared to outside school hours with no information on accumulation across the day (Harrington et al. 2011).

Defining bouts of sedentary time

As described in section 2.3.3, the recently updated Australia's Physical and Sedentary Behaviour Guidelines recommend children break up prolonged periods of sitting as often as possible (The Department of Health 2014). However, little is known about how children accumulate their sedentary time, including the length and frequency of 'prolonged' sitting. In order to effectively intervene, a greater depth of information is needed regarding how children accumulate their sedentary time and when longer uninterrupted bouts of sitting time are occurring. This can be determined through the assessment of the frequency of different sedentary bout lengths across defined periods of the weekday and weekend day. The first method for quantifying sedentary bouts with accelerometers was that of Chastin and Granat (2010) who developed a technique to analyse and quantify a "usual" sedentary bout length. This model calculates the length of the sedentary bout at which 50% of total sedentary time is accrued. This approach provides important information about the average duration of sedentary bouts and therefore may be used to identify people who are more likely to engage in long uninterrupted bouts of sedentary time. However, information regarding the frequency of different bout lengths would be useful in further understanding children's patterning of sedentary behaviour. Several studies have addressed this issue by examining pre-determined bout lengths and the frequency in which they occur or time spent in these bouts in pediatric populations and these are described below. Where pediatric examples are not available, definitions applied in studies of breaks and bouts in adolescents are discussed.

The study by Carson and Janssen (2011) defined a bout as lasting 30 minutes or more to capture the length of a typical TV programme (Carson & Janssen 2011). A limitation of that approach, however, is the inclusion of a 20% allowance of counts above 100 cpm, not including MVPA (referred to herein as a 'forgiveness' rule). For example, a bout stopped when ≥16 minutes out of a 20 minute period was above 100 cpm. This allowance was purposively formulated to replicate real world situations in which sedentary pursuits are broken with light intensity activity. Similarly Colley and colleagues (2013) defined a sedentary bout as lasting between 20 and 120 minutes (in increments of 20 minutes) and applied a 20% forgiveness rule. The 'forgiveness' rule applied in both these studies is problematic because "prolonged" sedentary time is not specifically assessed. In order to identify the threshold at which sedentary bouts are biologically meaningful, it is necessary to isolate uninterrupted (i.e. no forgiveness rule) sedentary time.

Two studies have examined uninterrupted bout lengths, i.e. with no forgiveness rule, using an ActiGraph accelerometer (Abbott, Straker & Mathiassen 2014; Carson, Stone & Faulkner 2014) and two using the *activ*PAL™ inclinometer

(Dowd et al. 2012; Harrington et al. 2011). Abbot and colleagues (2014) assessed the percentage of sedentary time spent in bouts of ≥30 minutes. Carson and colleagues assessed time spent in bout lengths of 1-4 mins, 5-9 mins, 10-19 mins, 20-29 mins and ≥30 mins. Harrington and colleagues (2011) and Dowd and colleagues (2012) used a range of measures of sitting bouts, including the mean number of sitting bouts, the mean length of a sitting bout and the frequency of sitting bouts ranging from <1 minute, 1-5 mins, 6-10 mins, 11-20 mins, 21-40 mins and >40 mins. In the ActiGraph and *activ*PAL™ studies of bouts, a bout was defined as commencing when an epoch of sedentary/sitting time was recorded and finished when an epoch recorded any other intensity (i.e. >100 cpm) of activity or standing/stepping.

Defining breaks in sedentary and sitting time

The ActiGraph studies described above (Abbott, Straker & Mathiassen 2014; Carson & Janssen 2011; Carson, Stone & Faulkner 2014; Colley et al. 2013), also assessed breaks in sedentary time. In these studies a break in sedentary time was defined as occurring when a consecutive series of epochs in which ≤100 cpm was the measured intensity was interrupted by an epoch in which the accelerometer counts exceed the counts that equated to ≤100 cpm (e.g. 25 counts/15s-epoch). Two studies have examined *activ*PAL™ determined breaks in sitting time (Dowd et al. 2012; Harrington et al. 2011) and assessed this as the mean daily frequency in which an individual had a postural transition from a sitting/lying posture to standing posture throughout the day.

2.6.2 Patterns of objectively measured sedentary behaviour

Temporal patterns in sedentary and sitting time

As described in section 2.6.2, three studies have examined temporal patterns of sedentary time in children (Bailey et al. 2012; Guinhouya et al. 2007; Steele et al. 2010). These studies differed considerably with regard to the time frames examined and include hour-by-hour patterns, and school versus non-school time (Steele et al. 2010), periods of the school day (i.e. class time, break time and after school) (Bailey et al. 2012), periods of the waking day (morning, noon, afternoon and evening) (Guinhouya et al. 2007) and sitting time during school time compared to non-school hours (Harrington et al. 2011).

In the UK SPEEDY study of 9-10 year olds, similar hour-by-hour patterns were observed across weekdays and weekend days. However, children spent more time sedentary outside school compared to non-school hours and this was significant for boys (Steele et al. 2010). Periods of the day were examined in a study of 103 children aged 8-11 years (Guinhoya et al. 2007). In that study the morning period (7am-11.59am) contributed the highest percentage to sedentary time in girls (37.6%) and boys (38.3%) (Guinhouya et al. 2007). However, an important consideration is that weekend day and weekday time were combined and periods of the school day were collapsed into time frames which overlapped between school time and discretionary time. Therefore, it is not possible to identify specific periods in which to target health promotion strategies and maximise opportunities to reduce overall sedentary time. A study of 10-14 year old children in the UK (Bailey et al. 2012), examined periods of the school day and reported that class time contributed 64% of children's total sedentary time and the after school period (until 6.30pm) comprised 26% of children's total sedentary time. In addition, that study reported girls spent a greater percentage of break time sedentary compared to boys. The high percentage of sedentary time during school hours indicates the school day is an important time within which to target reducing sedentary time. An important consideration of that study is the cut-point of <288cpm which may have resulted in an over-estimation of sedentary time. Using a direct measure of posture, a study of adolescent females (Harrington et al. 2011) reported no significant difference in the total time spent sedentary during school hours compared to outside school hours (4pm-10pm). However, in that study, periods within the school day were not examined.

Further research is needed which examines clearly defined periods across the day so as to inform specific windows of opportunity to maximise the effectiveness of health promotion strategies. To the best of the candidate's knowledge, no studies have examined temporal patterns of sitting time using objective devices that directly measure postural allocation. This is important to examine as the direct measure of postural allocation overcomes issues associated with the reliance on cut-points with hip-mounted accelerometers (section 2.4.2).

Breaks in and bouts of sedentary and sitting time

Two studies have described breaks in and ≥30 minute bouts of sedentary time among young people (Carson & Janssen 2011; Carson, Stone & Faulkner 2014). Using data from the NHANES 2003-2004 and 2005-2006 study, Carson & Janssen (2011), examined the number of breaks that occurred within every 30 minute bout of sedentary time among 2527 youth (6-19 years). That study reported 13.5% of a 30 minute bout of sedentary time was interrupted by breaks and 24.5% of total sedentary time was spent in bouts ≥30 minutes. In a study of 66 children, aged 10-12 years from New Zealand (Abbott, Straker & Mathiassen 2014), a lower percentage of sedentary time (16% on weekdays and weekend days) was spent in ≥30 minute bouts compared to youth in the US. However, the higher percentage reported by Carson and Janssen (2011) is likely to reflect the 'forgiveness rule' of 20% (section 2.6.2) which was applied and which may result in an over estimation of time spent in bouts ≥30 minutes.

Among adolescent females (n=102), aged 15-18 years from Ireland (Harrington et al. 2011), the frequency of bout lengths (<1 minute and 1-5, 6-10, 11-20, 21-40 and >40 minutes) was highest for 1-5 minutes and although the frequency was lowest for longer bout lengths (>20 minutes), the frequency of these bout lengths was significantly higher on weekdays compared to weekend days. Interestingly, the frequency of sedentary breaks was lower on weekend days (Frq=50) compared to weekdays (Frq=55).

If breaking up uninterrupted sedentary/sitting time is beneficial to health, this may have important implications for childhood intervention strategies, including the potential for school-based policies that focus on breaking up periods of sedentary time. Such an approach may be particularly relevant during class time periods when it may be feasible to break up prolonged sitting. A greater understanding of sedentary patterns and also the effects on various health parameters is therefore paramount. If breaking up sedentary/sitting time is just as important to health as reducing sedentary/sitting time, this will have important implications for future policy and practice.

2.7 Associations between screen time and objectively measured sedentary and sitting time

As identified in section 2.2.2, screen time, in particular TV viewing is the most frequently reported measure of sedentary behaviour (Tremblay et al. 2011); although screen time does not represent all the ways children can be sedentary (Ridley, Ainsworth & Olds 2008). However, given the dominance of screen time reduction in interventions to reduce sedentary behaviour (DeMattia, Lemont & Meurer 2007; Doak et al. 2006; Kamath et al. 2008; Rey-Lopez et al. 2008), it is important to ascertain whether or not screen time reflects overall sedentary time and longer, uninterrupted bouts of sedentary time. If time spent in different SBBs is indicative of children who engage in high levels of total sedentary time then simple behavioural questions may be useful in the identification of children who are at risk of a sedentary lifestyle. Conversely, if time spent in different SBBs do not identify children with high levels of sedentary time, the use of objective devices, which can measure total sedentary time and patterns of sedentary time, will be important for future research. Few studies have examined this association in children, and to the best of the candidate's knowledge no studies have examined this association with objectively measured breaks and bouts or *activ*PAL™ measured sitting time, sit-to-stand transitions or bouts of sitting time.

A study of Australian adults (n=2046) found that TV viewing time was positively associated with time spent in other self-reported sedentary behaviours among women, but not among men (Sugiyama et al. 2008). However, positive associations between screen time and other self- or proxy-reported sedentary behaviours has not been found in studies in youth (Biddle, Gorely & Marshall 2009; Marshall. et al. 2002). A study involving 2494 adolescents (aged 11-15 years) from the US and the UK examined clustering of different types of SBBs based on seven sedentary items from the Self-Administered Physical Activity Checklist (SAPAC) (Marshall et al. 2002). Correlations between the sedentary behaviours measured was low, suggesting that overall sedentary time may not be represented by one marker, such as TV viewing (Marshall et al. 2002).

In the UK, 1484 adolescents (mean age 14.7 years) from project STIL completed momentary assessment time-use diaries in time samples of 15 minutes; before school (0700 – 0845 hours), after school (1500 – 2345) and on the weekend (0700 – 2345) (Biddle, Gorely & Marshall 2009). TV viewing was negatively associated with other leisure-time sedentary behaviours. Although these studies of youth (Biddle, Gorely & Marshall 2009; Marshall et al. 2002) both comprise a large sample size, the age range encompassed is that of adolescents and the study populations are from the UK and the US. The generalisability to Australian children is therefore limited as the nature of adolescent's sedentary behaviour in these countries may not mirror that of Australian children.

Based on the results from these studies it is plausible that the measurement of screen time is not a good marker of sedentary time; however, these studies have only assessed one screen behaviour, TV viewing, against self-reported leisure time sedentary behaviours and may have missed important associations with overall sedentary time (Biddle, Gorely & Marshall 2009). Few studies have examined the association between time spent in different SBBs and objectively measured sedentary time in young people and the evidence is equivocal (Kiltsie et al. 2013; Verloigne et al. 2013). In 10-12 year olds from European countries there was insufficient evidence to suggest time spent in TV viewing and computer use reflect overall sedentary time (Verloigne et al. 2013). Conversely, a study of 9-10 year old children from the UK SPEEDY study reported a positive association between TV viewing time and accelerometer measured daily sedentary time (Kiltsie et al. 2013).

SBBs, in particular TV viewing, are inherently passive pursuits that may involve extended unbroken periods of sedentary time. Therefore, it is plausible that children who spend more time in screen-based pursuits may have fewer breaks and engage in longer bouts of sedentary time. A potentially important gap in the literature, therefore, is evidence of the association between different SBBs and objectively measured patterns of sedentary time. Furthermore, while accelerometers provide objective measurement of sedentary time, the reliance on cut-points means certain behaviours may be misclassified as sedentary (e.g. standing with little movement). SBBs are typically considered to be undertaken while sitting. Therefore, the objective assessment of sedentary time with a device that directly measures sitting time and postural transitions from a sitting to standing position may provide greater insight as to the relevance of time spent in specific SBBs to sedentary time and patterns. To the candidates knowledge there is no published evidence of the association between children’s time spent in specific SBBs and inclinometer-determined total sitting time and breaks in and bouts of sitting time.

2.8 Associations between sedentary behaviour and CVD risk factors among children

2.8.1 Adiposity

Time spent in different SBBs, total screen time and adiposity

Numerous studies have been conducted which have examined the association between children's time spent in different SBBs, in particular TV viewing, total screen time and adiposity. A synthesis of reviews (Appendix A.1) has been undertaken with the objective of providing an overview of the literature and issues pertaining to the strength of the evidence. A summary table of individual studies is presented in Appendix A.2 and these are discussed in Chapter 8.

Narrative reviews

A narrative review of studies with participants who were healthy and aged between two and eighteen years examined cross-sectional, longitudinal and intervention based studies (Rey-Lopez et al. 2008). Therefore, the search criterion of that review was broadly inclusive and a wide range of studies were included. Associations between TV viewing, playing e-games, computer use and CVD risk factors were reviewed separately for each SBB. Of the 71 studies reviewed, 46 were cross-sectional, 28 were longitudinal and four were interventions. Of the cross-sectional studies, there was a higher percentage that reported a positive TV viewing and playing e-games (in boys only) to be positively associated adiposity compared to the percentage of studies that reported a null association. Interestingly, a higher percentage of studies that reported a significantly positive association between TV and adiposity was also evident in the longitudinal studies. However, the pattern for studies of e-games observed with cross-sectional studies was not evident in longitudinal studies with just one study reporting a positive association between e-games and weight gain. In that review, no studies of computer use reported a positive association with weight gain. Of four intervention studies reviewed, only one reported a significant reduction in weight gain when TV viewing time was reduced.

A similar style of review of prospective observational studies was conducted by Must and Tybor (2005) who also concluded that decreased sedentary behaviour was protective against weight gain. However, the relevance was more pronounced before adolescence (Must & Tybor 2005). In that review of the evidence, screen time was treated as any combination of different SBBs and there was no differentiation between TV viewing, e-games or computer use. Therefore, it is not known if specific SBBs have a differential relation to adiposity. It is an important consideration that no quality criteria were applied in either of these reviews and therefore studies which may have important methodological limitations, such as small sample size, are likely to have been included. As the reviews only summarised the outcome reported in the studies, there is no information on the limitations of individual studies, such as controlling for potential confounding factors, in particular MVPA and diet which are key CVD risk factor influences (see section 2.2.3).

Systematic reviews

A systematic review of 170 studies, including cross-sectional, longitudinal, interventions and RCTs, examined associations between sedentary behaviours and a range of health outcomes in youth aged 5-17 years (Tremblay, LeBlanc, Kho, et al. 2011). The authors concluded there was sufficient evidence that watching TV for more than 2 hours is associated with adiposity. However, most of the studies examined were cross-sectional (n=119) and there was no differentiation in the results as to the type of SBB or differences by age group. Of 19 longitudinal studies, nine reported no association between TV viewing and adiposity. However, of eight RCTs, seven reported a reduction in weight associated with a decrease in TV viewing time.

A systematic review of 31 longitudinal studies in youth aged younger than 18 years applied 13 quality criteria to limit the review to studies that were adequate with regard to study population, study attrition, data collection and data analyses (Chinapaw et al. 2011). Of these, only nine were scored as being of high quality. Interestingly, there was a more consistent positive association between TV viewing and adiposity in high quality studies compared to studies that were not deemed to be high quality. Despite the evidence presented in high quality studies the authors concluded there to be insufficient evidence of a longitudinal association between TV viewing and adiposity. Similar to the review by Rey-Lopez (2008), the review only summarised the outcome reported in the studies and there was no information on limitations of individual studies or the inclusion of important confounding factors (i.e. SES, MVPA and diet) within the studies.

Meta-analysis

A meta-analytical review by Marshall and colleagues (2004) assessed 30 empirical studies of time spent in specific SBBs and adiposity in youth younger than 18 years. Effect sizes were reported for TV viewing and video game/computer use with adiposity. An important strength of the review is calculation of an effect size with adjustment for sampling error, measurement error (both of the dependent and independent variable) and dichotomisation of a continuously distributed measure of adiposity. The authors concluded there was a significant relationship between TV viewing (but not computer use and e-games) and adiposity; however, the effect size (r=0.088), was likely to be too small to be of clinical relevance. However, from a public health perspective, even a small effect size may have important health gains at a population level.

A meta-analysis of 34 randomised trials of interventions to reduce children's BMI (Kamath et al. 2008) concluded there were only small effects. However, an important consideration was that many of the studies were multi-faceted (e.g. comprised of physical activity, sedentary behaviour and/or diet components), so it is difficult to determine if reduced levels of screen time resulted in a decrease in BMI or if this was due to other aspects of the intervention such as increased physical activity. Furthermore, with respect to both these reviews a requirement of a meta-analysis is conformity to a set of data management and analysis criteria to measure effect size. Consequently, while specific criteria were applied to studies in order to calculate an effect size, the compromise is the exclusion of potentially good quality and relevant studies.

The majority of studies included in the above reviews reported at least a small to moderate positive association between screen time, in particular TV viewing, and adiposity; however, some reported a null association. Overall, the level of evidence is weak and causality cannot be established. However, further research is required which assesses different types of SBBs (TV, electronic games, computer use) compared to total screen time and controls for important confounders, notably MVPA and diet which are important lifestyle influences on CVD risk factors. In addition, as time spent in screen based pursuits may not reflect overall sedentary time (Verloigne et al. 2013), studies which objectively measure total sedentary time are important.

Objectively measured sedentary time and adiposity

Appendix B.1 provides a synthesis of studies that have examined the cross-sectional association between objectively measured sedentary time and adiposity in children. The results of those studies are inconclusive with most studies reporting a null association (Carson et al. 2014; Carson & Janssen 2011; Chaput et al. 2012; Cliff et al. 2012; Ekelund et al. 2007; Ekelund et al. 2012; Hay et al. 2012; Mitchell et al. 2009; Purslow et al. 2008; Steele et al. 2009; Thompson et al. 2009; Treuth et al. 2005); yet some reporting a significantly positive association (Chinapaw et al. 2012; Colley et al. 2013).

The contrast in findings is likely to reflect methodological differences in the adjustment for important confounders and accelerometer protocols. For example, there has been a lack of consistency regarding the statistical adjustment for diet and physical activity, in previous studies (Purslow et al. 2008; Thompson et al. 2009; Treuth et al. 2005). Among studies that controlled for MVPA (Carson & Janssen 2011; Chinapaw et al. 2012; Cliff et al. 2012; Colley et al. 2013; Ekelund et al. 2012; Mitchell et al. 2009; Steele et al. 2009), the definition of MVPA varied considerably between studies, ranging from 1500cpm (Colley et al. 2013) to 3600cpm (Mitchell et al. 2009), which makes interpretation of data difficult in terms of the level of intensity that was assessed as a confounder. Similar issues are evident with the measurement of diet. Among studies that did adjust for a measure of diet quality (Carson & Janssen 2011; Chaput et al. 2012; Cliff et al. 2012), the measure varied with regard to the groups of food and beverage intake that were included in the score, the recall time period and the quantity scale recorded. Interestingly, in the studies that reported a positive association between sedentary time and adiposity (Chinapaw et al. 2012; Colley et al. 2013), diet was not included as a confounder in the analysis and therefore may account for the positive association reported.

Another important consideration is the protocols applied to accelerometer data management across studies. Twenty minutes of consecutive zeroes is widely used to reflect non-wear time in children (Cain et al. 2013). However, several previous studies may have under estimated sedentary time by applying a lower threshold of 10 minutes of consecutive zeroes (Ekelund et al. 2007; Martinez-Gomez, Eisenmann, et al. 2009; Purslow et al. 2008; Steele et al. 2009), and other studies may have overestimated sedentary time by applying a higher threshold of 60 minutes (Chaput et al. 2011; Colley et al. 2013; Ekelund et al. 2012). Furthermore, Colley and colleagues (Colley et al. 2013) included a two minute tolerance of counts between zero and 100 and these decisions are likely to inflate monitor wear time and sedentary time (Dunstan, Howard, et al. 2012). Surprisingly, non-wear criteria were not reported at all in some studies (Mitchell et al. 2009; Thompson et al. 2009; Treuth et al. 2005), thus the extent to which the outcome variables were influenced by these criteria cannot be considered in the interpretation of the results. Additionally, with the exception of one study (Steele et al. 2009), the epoch length used was typically one minute which may mask intermittent bursts of higher intensity activities because counts are summed across the 60 second time frame (Nilsson et al. 2002).

The cut-point used to define sedentary time is also an important factor. While the recommended cut-point of ≤100 cpm was used to define sedentary time in this doctoral thesis (Evenson et al. 2006; Ridgers et al. 2012; Treuth et al. 2004), the EYHS used a cut-point of <500 cpm (Ekelund et al. 2007) and the ALSPAC study used <200 cpm (Mitchell et al. 2009). Sedentary time is therefore likely to have been overestimated with the inclusion of light- to moderate-intensity activity in those studies (Ridgers et al. 2012) and may account for the null association reported between total sedentary time and adiposity in previous research.

2.8.2 Blood pressure

SBBs and blood pressure

As described in Appendix A.3, several cross-sectional studies have reported a positive association between TV viewing and SBP or DBP (Hee-Taik et al. 2010; Martinez-Gomez, Tucker et al. 2009; Pardee et al. 2007; Wells et al. 2008) in young people. However, none of these studies adjusted for diet, only one of these studies adjusted for MVPA (Wells et al. 2008), and only one of these studies adjusted for adiposity (Martinez-Gomez et al. 2009).

As discussed in section 2.2.1, children who are overweight or obese are more likely to have additional CVD risk factors such as raised blood pressure (Bell et al. 2007; Freedman et al. 2007). Martinez-Gomez and colleagues (2009) reported a positive association between TV viewing and blood pressure after adjusting for adiposity; however, that study did not control for MVPA. Conversely, a study of 1921 European youth reported a null association between TV viewing and blood pressure after adjusting for MVPA and adiposity (Ekelund et al. 2006).

In a study of 10-18 year olds in Korea (Hee-Taik et al. 2010), the measure of screen time included computer use. However, a study of 3-8 year old children in the US (Martinez-Gomez, Tucker et al. 2009) examined the association between TV viewing and computer use with blood pressure separately and reported a positive association for TV viewing but not computer use. This finding suggests screen behaviours may have different relevance to blood pressure and should be treated as distinct behaviours in future studies.

Objectively measured sedentary time and blood pressure

Several cross-sectional studies have examined the association between accelerometer determined sedentary time and blood pressure among children (Appendix B.1) (Carson & Janssen 2011; Ekelund et al. 2007; Martinez-Gomez, Eisenmann, et al. 2009; Cliff et al. 2013; Chaput et al. 2013; Hay et al. 2012; Ekelund et al. 2012). Of these studies, the majority have reported a null association between sedentary time, with only two studies reporting a positive association (Martinez-Gomez, Eisenmann, et al. 2009: Ekelund et al. 2007). While the AFINOS study of 13-17 year olds (n=210) in Spain (Martinez-Gomez, Eisenmann, et al. 2009) reported a positive association between sedentary time and blood pressure, it is an important limitation that MVPA and diet were not adjusted for. Furthermore, the older age group of that cohort means they have had a longer life-time exposure to sedentary behaviour. Equally in the EYHS (Ekelund et al. 2007) (Ekelund et al. 2007) of 9-10 and 15-16 year olds (n=1709), diet and MVPA were not adjusted for. In addition, a threshold of ≤500cpm was used to define sedentary which is likely to result in the inclusion of higher intensities of activity that may be beneficial to health.

2.8.3 Lipid profiles

Screen time and lipid profiles

Several cross-sectional studies have reported the association between screen time and a measure of lipids (Appendix B.3) (Carson & Janssen 2011; Ekelund et al. 2006; Hancox, Milne & Poulton 2004; Hee-Taik et al. 2010; Martinez-Gomez et al. 2010). In the EYHS there was no association between TV viewing and TG or HDL-C (Ekelund et al. 2006). As previously discussed, however, that study did not measure weekend TV viewing time. The remaining four studies reported a positive association with at least one lipid marker. However, important differences are evident in study design including; sample size which ranges from 425 (Martinez-Gomez et al. 2010) to 2527 (Carson & Janssen 2011); differences between all studies with regard to the measurement and definition of screen time, and control of important potential confounding factors, such as puberty, which has been shown to be inversely associated with boys HDL-C at puberty (Belay, Belamarich & Racine 2004). The study by Carson and colleagues, however, measured non-HDL-C which has been identified as a potentially more appropriate screening measure for abnormal lipid profiles in young adults as it is does not require a fasted blood sample and is associated with early (subclinical) atherosclerosis in young people (Frontini et al. 2007). This risk factor, however, has not been established in children.

A longitudinal study that examined time spent in different SBBs and lipids reported a positive association between TV viewing time and total cholesterol at age 26 after controlling for body weight at age 5 and self-reported physical activity at age 15 (Hancox, Milne & Poulton 2004). However, it is not possible to ascertain if the raised total cholesterol levels observed were due to higher HDL-C, which is beneficial to CVD health or higher LDL-C, which is detrimental to CVD health. In addition physical activity was self-reported and the blood sample was not fasted which is needed to assess regular levels of lipoproteins.

Objectively measured sedentary time and lipid profiles

A study of youth using NHANES data reported no association between sedentary time and a range of lipid measures after adjusting for important confounders (Appendix B.1) (Carson & Janssen 2011). Conversely, earlier studies have reported a positive association between sedentary time and lipids (Ekelund et al. 2007; Martinez-Gomez, Eisenmann, et al. 2009). However, those studies did not control for MVPA, adiposity and diet. In addition, as previously discussed the EYHS applied a high accelerometer cut-point (500cpm) to define sedentary time which is likely to have inflated the total daily volume of objectively measured time spent sedentary.

Conclusion

The results from the cross-sectional studies reviewed to date provides weak evidence of an association between screen time and CVD risk factors. A key limitation of these studies is the lack of adjustment for diet, MVPA and adiposity. This will be an important consideration for future studies so as to ascertain the association between different SBBS and CVD risk factors that is independent of MVPA and diet, and adiposity (in studies of blood pressure and lipids). In addition, many studies did not differentiate between TV viewing, e-games and computer use. Therefore, further research is needed which assess the differential cardiovascular health implications of individual screen behaviours.

There is little evidence from the studies reviewed to suggest objectively measured total sedentary time is detrimentally associated with CVD risk factors in children. However, the reliance on cut-points to define sedentary means light-intensity activities (standing with little movement) may be misclassified as sedentary. In addition, there is wide variability across studies in controlling for MVPA and diet as well as differences in the accelerometer protocols applied. These issues may explain the null associations reported to date. Therefore studies which control for MVPA and diet as well as studies that measure sitting time will be important in future research of children's sedentary behaviour and CVD risk factors. To the best of the candidate's knowledge there is no published research of the association between sitting time and CVD risk factors in children. In addition, emerging evidence from studies of adult cohorts suggests the way in which sedentary time is accumulated (breaks and bouts) may be beneficial to health

(Dunstan, Kingwell, et al. 2012; Healy, Dunstan, et al. 2008; Healy et al. 2011); however, this has not been established in children.

2.9 Patterns of sedentary time and CVD risk factors

The importance of examining sedentary patterns is demonstrated by studies in animals (Bey & Hamilton 2003) and overweight adults (Dunstan, Kingwell, et al. 2012) that have shown the potential for adverse physiological changes to be reversed by interruptions in sedentary time. Bey and Hamilton (2003) found low LPL activity was reversed following moderate intensity activity performed intermittently over four hours with 30 minutes of rest each hour. Dunstan and colleagues (2012) showed that two minute interruptions (of light or moderate intensity activity) to sedentary time, at 20 minute intervals, significantly lowered glucose and insulin compared to uninterrupted sitting in sedentary overweight adults. The finding of Dunstan and colleagues (2012) is supported by evidence from adult cross-sectional studies which suggest cardiovascular health benefits may be gained by breaking up extended periods of sedentary time (Dunstan, Kingwell, et al. 2012; Healy, Dunstan, et al. 2008; Healy et al. 2011).

2.9.1 Breaks in and bouts of sedentary time and CVD risk factors

Breaks in and bouts of sedentary time and CVD risk factors in children

Few studies have examined cross-sectional associations between sedentary breaks, bouts and CVD risk factors in children and those studies that have examined this, have reported null (Carson & Janssen 2011) or minimal associations (Carson, Stone & Faulkner 2014; Colley et al. 2013). In 6-18 year olds, ≥30 minute bouts of sedentary time and a lower frequency of breaks in sedentary time were not associated with higher WC, SBP, TC or non-HDL-C after controlling for MVPA and diet (Carson & Janssen 2011). In a study of 6-19 year old youth from the Canadian Health Measures Survey (CHMS) few associations were observed between breaks in and bouts of sedentary time (20, 40, 60, 80, 100 and 120 minutes) or breaks in sedentary time and WC or BMI in girls in any of the age groups between 6 and 19 years. However, 40 minute bouts were positively associated with WC and 80 minute bouts with WC and BMI in 11-14 year old boys independent of MVPA. Conversely, in a study of youth from Project BEAT in Canada shorter bout lengths of 1-4 and 5-9 minutes were adversely associated with zBMI (Carson, Stone & Faulkner 2014) independent of MVPA. As discussed in section 2.7.1, the longer non-wear time definition (≥60 minutes) and the one minute epoch length applied to these studies may miss transitions to short bursts of light intensity activity which may have beneficial health effects (Healy et al. 2007) and consequently yield a higher frequency of longer bouts. Furthermore, Carson and colleagues (2011) and Colley and colleagues applied a forgiveness rule of 20% to the bout lengths which (section 2.1.2) is problematic because light-intensity physical activity and breaks in sedentary time, which have been found to have beneficial associations with health (Healy et al. 2007; Healy, Dunstan, et al. 2008), may be included in the bout.

Research examining the associations between patterns of sedentary behaviour and CVD risk factors in children is in preliminary stages. Further research is needed using bout lengths that are biologically meaningful in this age group. Furthermore, the use of inclinometers to assess sitting time is a critical gap within this emerging domain of sedentary behaviour research.

2.10 Summary

The amount of time spent sedentary in the studies discussed in this literature review indicate children are engaging in high levels of sedentary behaviour. However, little is known about when children spend the most time sedentary and how that time is accumulated. In addition few studies have used measures which directly assess sitting time to examine children's sedentary patterns.

Evidence regarding children's sedentary behaviour and CVD risk factors is predominantly derived from studies of TV viewing and total screen time. Variability in the definition of screen time is evident and few studies have controlled for diet, adiposity and MVPA. Further research is needed that examines the separate components of screen time (TV, computer use and electronic games) and CVD risk factors, controlling for diet, adiposity and MVPA.

Few studies have assessed the association between screen time and objectively measured sedentary time and have reported mixed findings. A greater understanding of the appropriateness of different types of screen based pursuits and total screen time as an indicator of overall sedentary time is needed to identify the most accurate measures of sedentary behaviour in field-based research.

A limited number of studies are available which have objectively assessed the association between sedentary time and CVD risk factors among primary school-aged children. Similar to the screen time studies, wide variability in adjusting for important confounders is also evident across studies. The inclusion of MVPA and diet will be an important consideration in future studies of sedentary time and CVD risk factors. The availability of objective evidence comes from studies which have used accelerometers to determine sedentary time. To overcome issues associated with accelerometer cut-points of sitting time, the use of devices which directly measure sitting will be an important dimension of future research.

Furthermore, the available evidence of associations between objectively measured sedentary time and CVD risk factors is based on total daily sedentary time; however, it may be that the way in which sedentary time is accumulated (e.g. the length of bouts and the frequency of breaks in sedentary time) has important health implications. To date few studies have measured the association between patterns of children's sedentary time and CVD risk factors. Further investigation is therefore needed to identify when sedentary time is occurring, how it is accumulated and the importance of the duration of sedentary bouts and frequency of breaks to cardiovascular health.

Based on these critical gaps in the literature this doctoral thesis comprises several aims which will address gaps and limitations in the current evidence base.

2.11 Thesis aims

The aims of this thesis are to:

1. Describe the prevalence of children's time spent in different SBBs (TV viewing, e-games and computer use) and examine the associations with CVD risk factors.

2. Determine the volume and patterns (breaks and bouts) of children's objectively measured sedentary (accelerometer determined) and sitting (inclinometer determined) time within a total weekday and weekend day and discrete periods across the day.

3. Evaluate the association between time spent in specific SBBs and objectively measured volume and patterns of sedentary and sitting time.

4. Examine the association between children's sedentary and sitting patterns and CVD risk factors.

Chapter 3
Methods of the Transform-Us! and LOOK studies

3.1 Introduction

As discussed in Chapter 2, emerging evidence suggests that sedentary behaviour may be a behavioural risk factor for adverse cardiovascular health in children independent of MVPA and diet energy density. Furthermore, in addition to the amount of time spent sedentary, the way in which it is accumulated (breaks and bouts) may be important to cardiovascular health. However, little is known about the independent associations between TV viewing, e-games and computer use, total time spent sedentary and sitting, the way these are accumulated and associations with children's CVD risk factors. Additionally, in order to effectively intervene to reduce children's sedentary behaviour it is important to understand what children are doing when they are sedentary and when periods of high engagement in sedentary behaviour occur. In line with the updated Australia's Physical Activity and Sedentary Behaviour Guidelines (The Department of Health 2014) and the recommendation that sedentary be equated with sitting (SBRN 2012), measures that allow for the assessment of posture are needed. To address the thesis aims, data are drawn from two large scale studies; Transform-us! and the Lifestyle of Our Kids (LOOK) study.

3.2 Role of the Candidate in the Transform-Us! study

Baseline data from the Transform-Us! randomised controlled trial (RCT) was utilised in this thesis. While the candidature commenced after that data had been collected, the candidate was wholly involved in the data collection during subsequent data collection time points. This involved visiting schools, supporting children to complete their survey, undertaking anthropometric and blood pressure measures and fitting ActiGraph accelerometers and *activ*PAL^{TM} inclinometers. The candidate assisted with following-up missing data, including calling parents to provide a reminder for the child to undertake a blood sample and following up monitors that had not been returned. The candidate provided key input into the development of the Excel Macro for the generation of bouts and breaks data as well as the syntax for the breaks and bouts analysis. Lastly, the candidate performed data cleaning checks for the baseline data set, including the anthropometric, survey and blood pressure data. This involved checking for obscure values, missing values and values that did not fall within the expected range and cross-referencing these values with the original data collection forms and parent questionnaire.

3.3 Chapter aim

The aim of this chapter is to describe the study design, measures, data collection and data management procedures used to obtain data from the Transform Us! and LOOK studies.

3.4 Study design and ethical approval

Transform Us! was a cluster RCT with a 2x2 factorial design (Salmon et al. 2011). Ethical approval was obtained from Deakin University Human Research Ethics Committee (EC141-2009), Department of Education and Early Childhood

Development (2009-000344) and Catholic Education Office (Project Number 1545).

LOOK was a 4-year longitudinal quasi-experimental study which investigated relationships between lifestyle factors and health in primary school children. LOOK was approved by the ACT Department of Education and Training (2013/00082-5), the Australian Institute of Sport Ethics Committee (20060606) and the ACT Health Committee for Ethics in Human Research (ETH.9/05.697).

3.5 School recruitment and consent

3.5.1 Transform-Us!

Recruitment of participants in the Transform-Us! study took place at the school level. To be eligible for participation, schools were required to have an enrolment of greater than 300 children, have two classes that were inclusive of Year 3 (i.e. may include a Year 3/4 composite class), have no previous involvement in a Deakin University study and be located within a 50km radius of Melbourne Central Business District (CBD) (Salmon et al. 2011).

Three-hundred and sixty-seven out of a possible 2413 schools (15.2%) in Victoria met the inclusion criteria. The eligible schools were grouped into quintiles based on the Socio-Economic Indexes for Areas (SEIFA) score (suburb disadvantage score) (Australian Bureau of Statistics 2006). Schools from the first (n=74), third (n=74) and fifth (n=71) SEIFA quintiles were included to represent low, mid and high SEIFA strata respectively.

School principals were provided with a plain language statement and consent form (Appendix C.1) which was required to be signed by themselves and the school council/board. Eight schools from the low SES stratum, eleven schools from the mid SES stratum and one school from the high SES stratum agreed to participate, resulting in a total of 20 schools.

Prior to baseline data collection schools were randomised to one of three intervention (I) groups: sedentary behaviour (SB-I); physical activity (PA-I); combined SB and PA (SB + PA-I); or current practice control group. For the purpose of this thesis baseline data were utilised (collected between February 2010 and May 2010) when children were aged 7-10 years.

3.5.2 LOOK

Recruitment of participants in the LOOK study took place at the school level (Telford et al. 2009). Thirty Government funded schools in the outer suburbs of Canberra were identified that were homogenous with regard to facilities and had an average household income that was representative of the mean for Australian city dwellers. Twenty-nine of the schools agreed to participate (97.7% response rate).

School principals were provided with a plain language statement and consent form (Appendix D.1) which was required to be signed by themselves and the school council/board. Schools were randomly allocated to the intervention (n=13) or the current practice control (n=16) prior to baseline data collection, at the end of 2005. For the purpose of this thesis, data have been utilised from the 2009 data collection point (time-point three) of children in the control group in Year 6 (aged 11-12 years). This LOOK cohort was selected in order to match the data collection procedure for sedentary time in Transform-Us! with ActiGraph accelerometers. Prior to post-intervention in LOOK, pedometers were used to assess physical activity and therefore the data was not comparable with Transform-Us!

3.6 Participant recruitment and consent

3.6.1 Transform Us!

Between December 2009 and January 2010 parents with a child/children in Year 3 for the school year of 2010 (n=1606) were sent an information and consent pack (Appendix C.2). In addition, a short 10-15 minute presentation was made to the children during appropriate class times that were booked in with the teachers. The procedures of the study were explained to the children and they were able to ask questions.

The information and consent pack invited families to “participate in the evaluation of a new and exciting approach for reducing children’s time spent sedentary and promoting physical activity at school and at home.” Parents were informed that the school’s Principal and board had given approval for the school to be involved in the two year Transform-Us! study, the components of the study had been developed in conjunction with the Victorian Essential Learning Standards for Level 3, and the programme had been approved by relevant ethics committees. In addition, parents were informed of the measures that would be taken, the time points for each measure and the confidential nature of the results.

The letter to the parent/carer also explained they were not obliged to participate and were able to nominate which assessment components they gave consent for their child to participate in (i.e. ActiGraph, *activ*PAL^{TM}, anthropometrics, blood pressure, blood sample). Thirty-seven percent of parents (n=596) provided consent for their child's involvement in at least one of the assessment components and 21% (n=341) for all components at baseline.

3.6.2 LOOK

At baseline (2006), the parents of Year 2 children (n=900) were provided with a plain language statement and consent form (Appendix D.2) for their own and their child's participation in the study and assessment components. The plain language statement described the LOOK study and the research questions the study aimed to answer. In addition, it described each of the measurements children were asked to participate in, the requirements of each measurement and the timeline for the testing periods. Answers to eight frequently asked questions (e.g. Will my child miss many classes?) were also provided.

Seven-hundred and eight children aged 7-8 years had active parental consent to participate in all of the assessment components (response rate=78%) at time-point one; however, children were able to withdraw their consent for any component of the assessment throughout the study. Three-hundred and fourteen of those children were allocated to the control group. At time-point three (2009), 97 children had been lost at follow up, leaving 217 children from the original control group with consent for at least one assessment component (69%).

3.7 Measures and procedures

Comparable measures were used in the Transform-Us! and LOOK studies; however, some differences in the number of assessments were evident and these are described in Table 3.1. The LOOK study did not collect data using *activ*PALs or time spent in different SBBs and the Transform-Us! study did not collect dual energy x-ray absorptiometry (DXA); these measures are therefore described separately.

Table 3.1 Comparability of Transform-Us! and LOOK measures

Measure	Transform Us!	LOOK
ActiGraph	ActiGraph GT3X	ActiGraph GT1M
*activ*PAL™	activPAL™	na
Height	2 measures	1 measure
Weight	2 measures	1 measure
WC	2 measures (Nearest 0.1cm)	1 measure (Nearest 1cm)
DXA	na	Canberra Hospital 1 measure
Blood pressure	Average of 4 readings	Average of 2 readings
Bloods	Pathology Centre	Nurse at school
SBBs	Parent reported	na
SES	Parent education	Parent education
Diet	Parent questionnaire	Parent questionnaire

Abbreviations: WC refers to waist circumference; DXA, dual energy x-ray absorptiometry; SES, socio-economic status;
na, this item was not assessed

3.7.1 Objectively measured sedentary time

As described in Chapter 2, accelerometers record acceleration in a non-invasive manner and are an accepted assessment tool of children's physical activity and sedentary behaviour (Reilly et al. 2008). Both the Transform-Us! study and the LOOK study used the most up-to-date ActiGraph (www.theactigraph.com) available at the time of data collection; the GT3X (utilising the normal frequency filter) and GT1M, respectively. These monitors have acceptable comparability (Robusto & Trost 2012) and data were therefore pooled for analyses in Chapters 5 and 9. The uniaxial function of the ActiGraph was utilised to measure activity counts in the vertical plane as this is currently the usual way to analyse data from accelerometers (Robusto & Trost 2012).

Each child was assigned a specific ActiGraph and the monitor number was recorded prior to the school visit. Children were fitted individually with their activity monitor by a trained researcher who explained how to wear the accelerometer. Children were asked to wear the ActiGraph for eight consecutive days on a belt positioned over the right hip. The ActiGraph is fastened with a clip on the side of the waist and is easy to remove and re-fasten. Children were instructed to remove the ActiGraph when they went to bed at night and for water-based activities (such as swimming and bathing) and were advised they could remove it during contact sports if needed.

Children from the Transform-Us! Study were given a thank-you gift (e.g. yoyo, drink bottle, bouncy ball) when the ActiGraph (and *activ*PAL™, where relevant) was returned. Children from the LOOK Study were given a gift voucher of $10 at the end of the study to thank them for their participation.

3.7.2 Objectively measured sitting time

The Transform-Us! Study measured sitting time using the *activ*PAL™ (PAL Technologies Ltd, Glasgow, Scotland) inclinometer. As described in Chapter 2, the *activ*PAL™ is a small unobtrusive device which distinguishes sitting time from standing (Grant et al. 2006).

The *activ*PAL™ was placed into a purpose-designed elastic garter with a pocket into which the *activ*PAL™ was sewn in place by research staff. The garter fastens at the anterior aspect of the mid-thigh with a velcro strap and it is therefore easy to remove and re-fasten. Children were asked to wear the *activ*PAL™ for eight consecutive days. Children were instructed to remove the *activ*PAL™ when they went to bed at night and for water-based activities (such as swimming and bathing) and were advised they could remove it during contact sports if needed.

3.7.3 Parent-proxy reported time spent in specific SBBs

In Transform-Us!, children's time spent in TV viewing, e-games and computer use on weekdays and weekend days was assessed with a parent/carer questionnaire (Appendix C.3). A proxy-report survey method was used because self-report surveys are not recommended in children under the age of 10 years (see section 2.4.1). Questions about children's time spent in these screen-based pursuits have been used previously by the research team (Salmon et al. 2008; Salmon et al. 2005) and their measurement has acceptable reliability and validity (Salmon et al. 2008). Question 21 (a-d; Appendix C.3), obtained information about four types of SBBs: a) TV, videos and DVDs; b) electronic games such as PlayStation ©, Nintendo ©, computer games; c) Nintendo Wii; and d) computer and internet (excluding games). Item 'c' was not utilised in this doctoral thesis as it is considered as active gaming (Graves et al. 2007; Graves, Ridgers & Stratton 2008).

For each of the different SBBs, the parent was asked to report whether the child usually does this activity during a typical week (yes/no), the total hours/minutes spent in the activity from Monday to Friday, and on the weekend (Saturday and Sunday).

3.7.4 Child information and family demographics

Transform-Us!

Information about the child in the study and the general health status of that child was obtained from the parent questionnaire (Appendix C.4). Questions 11 to 13 and question 15 obtained specific information about the child; including, date of birth (Q11), sex (Q12), class Year in 2010 (Q13) and whether or not the child has a disability or suffers from poor health (Q15). Detail was required if the answer was ‘yes’ to question 15.

Family demographic information was also obtained from the parent questionnaire (Appendix C.4). Question 47 required the respondent to tick the box applicable to their relation to the child (e.g. mother, father, grandparent). Question 49 obtained the age of the respondent in years. Questions 51-54 and 58 obtained information regarding marital status, country of birth, whether English was spoken at home, highest level of schooling, and employment status. Each of these questions required the respondent to tick the box most applicable.

LOOK

A family questionnaire, completed by a parent or carer of the child in the LOOK study during 2009 (time-point 3), was utilised to obtain demographic characteristics of the family (Appendix D.3). The 2009 questionnaire did not collect data regarding parent country of birth or education as this information was obtained in the 2006 family questionnaire (Appendix D.4). Therefore these characteristics were obtained from the 2006 questionnaire when the study commenced (i.e. time point one; Appendix D.4). Sex of the child and date of birth were collected by the research nurse during the school visit.

In the 2009 questionnaire, items 1, 2, 4, 5, 6 and 8 asked the respondent to report the socio-demographics of the family. Question 1 required the respondent to tick whether they are male or female. Question 2 asked the respondent to give their age in years. Question 4 obtained information on the respondents occupation. Question 5 required the respondent to tick the box which best describes their current employment. Questions 6 and 8 required the respondent to tick the box most applicable to their marital status and relationship to the child respectively. The 2006 questionnaire obtained information on the highest level of education completed by the parent (Question 6) and the parent's country of birth (Question 7).

3.7.5 Dietary intake

Usual dietary intake of the child was assessed by the parental proxy-report in Transform-Us! (Appendix C.5) and the 2009 LOOK family questionnaire (Appendix D.3). The reliability of parent-proxy reports of their child's usual food intake is supported by the literature (Basch et al. 1990; Dennison, Jenkins & Rockwell 2000).

Transform-Us!

Questions about the child's diet (Q32-Q36) included eight food items and two beverage items previously identified from the National Nutrition Survey for the target age groups (8-12 years) as important contributors to energy and fat intake, and thus the energy density of the diet (Australian Bureau of Statistics 1997).

LOOK

Parents reported the child's consumption of takeaway and fast food (Q40), soft drink (Q42) and sweetened juices (Q43) during a normal week.

3.7.6 Anthropometric and health measures

Height, weight and WC were measured in private at the child's school by trained research staff (Transform-Us!) or a research nurse (LOOK). Two measures were taken in Transform-Us! and one in LOOK (Table 3.1).

Height

Measurements were taken to the nearest 0.1cm using a SECA portable stadiometer (mod 220; www.seca.com). In Transform-Us! the average of the two measures was calculated. Where a discrepancy of greater than 0.5cm was noted a third measurement was taken by a second researcher and the average of the three measurements was calculated.

Weight

Weight was measured to the nearest 0.1kg using portable electronic Wedderburn Tanita scales (mod 1582; www.wedderburn.com.au). In Transform-Us! the average of the two measures was calculated. Where a discrepancy of greater than 0.5kg was noted a third measurement was taken by a second researcher the average of the three measurements was calculated.

Waist circumference

In order to reduce measurement error of waist circumference it has been recommended that a uniform measurement protocol is applied, training is provided and repeated measurements are taken (Verweij et al. 2013). Waist circumference was measured using a narrow (<7mm) flexible steel tape at the narrowest point between the bottom rib and the iliac crest, in the midaxillary plane against the skin or over light clothing (Garnett et al. 2005). Where narrowing between the bottom rib and the iliac crest was not evident the mid-point was used (Katzmarzyk et al. 2004). The measurement was taken at the end of a gentle expiration. In Transform-Us! two measurements were taken, one each by two different researchers and the average was calculated from the two measurements. In line with the recommendation by Verweij and colleagues (2013), a third measurement was taken by another researcher if there was a discrepancy of greater than 1 cm and the average of the three measurements was calculated. The measurement was taken to the nearest millimetre in Transform-Us! and to the nearest centimetre in the LOOK study.

Dual energy x-ray absorptiometry (DXA)

Total body and regional body composition was measured using dual energy x-ray absorptiometry (DXA, Hologic Discovery QDR Series, Hologic Inc., Belford, MA, USA) in LOOK only. Fat mass and percentage body fat was generated with QDR Hologic Software Version 12.4:7. Children were instructed to attend the Canberra Hospital during school hours and DXA scanning was undertaken by a trained technician.

Blood pressure

In Transform-Us!, resting blood pressure was measured in accordance with standard procedures and recommendations (National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents 2007). After a silent two-minute seated rest, resting blood pressure was measured on the right arm using the OMRON HEM-907 (http://www.omronhealthcare.com.au) automatic digital blood pressure machine. Each child was fitted with an appropriately sized paediatric cuff. Three measurements were taken one minute apart on two occasions, one week apart. The first measurement was discarded from visit one and two and the average was taken from the remaining four measurements. In the LOOK study the same protocol and model of blood pressure machine was used; however, two measurements were taken on one occasion and the average of these was calculated.

Blood sample

Consenting children in the Transform-Us! study were provided with a Pathology slip, fasting instruction sheet (Appendix C.6) and EMLA® cream on day 1 of data collection. EMLA® is a dermal anaesthetic topical cream that is applied to the skin one hour prior to blood collection to numb the skin and reduce any pain or discomfort that may be experienced during venepuncture. Children attended a conveniently located Melbourne Pathology Clinic in the morning after an overnight fast to provide a 16.5mL blood sample by a trained Phlebotomist. Samples were transported from the various clinics to the Melbourne Pathology laboratory under controlled conditions for analysis by qualified technicians. Melbourne Pathology sent hard copies of the results for each of the participants to the investigators at Deakin University.

In the LOOK study, fasted blood samples were collected from consenting children by a Paediatric nurse during the morning of the school visit. Breakfast was supplied to children after the sample had been collected. Parents were provided with an instruction sheet regarding their child's overnight fast (Appendix D.5). Blood samples were analysed by qualified technicians at Canberra Hospital.

3.7.7 Completion rates for assessment components

Transform-Us!

Just over 60% of children from Transform-Us! who had parental consent completed at least one assessment item (Table 3.2). Thirty percent of children completed all assessment components.

LOOK

Among families that provided consent, the completion rate for assessment components of children in the control group (Table 3.2) at time-point three was at least 80% for each item. Fifty two percent of children completed all assessment components.

Table 3.2 Completion rates of assessment components†

	Transform-Us! (n=596)		LOOK (n=217)	
Assessment item	**n**	**%**	**n**	**%**
Parent survey	446	74.8	176	81.1
ActiGraph	512	91.9	209	96.3
*activ*PAL™	205	95.8*	na	
Blood pressure	477	84.3	212	97.7
WC	570	97.1	211	97.2
Height/weight	568	96.9	216	99.5
DXA	na		201	92.6
Bloods	219	61.2	191	88.4
All components	102	29.9	113	52.1

* Not all children were offered the opportunity to wear the *activ*PAL™ due to the limited number of devices available; the assessment component was available to a subsample of 214 children.

† Assessment completion rate as a percentage of children who provided consent for that assessment component.

Abbreviations: WC refers to waist circumference; DXA, Dual Energy x-ray Absorptiometry; na, this item was not assessed

3.8 Data management

3.8.1 ActiGraph and *activ*PAL™ data

A customised Excel Macro, developed by the Centre for Physical Activity and Nutrition Research, was used to process the ActiGraph and *activ*PAL™ files. For all available files, a complete corresponding list of file names (i.e. child ID), child's age and school code number were entered into the Excel Macro. Periods of the day, non-wear time and epoch length were entered into the Excel Macro for ActiGraph and *activ*PAL™ files. Additionally, cut-points for sedentary time and

MVPA were defined and entered into the Excel Macro for ActiGraph data processing before it was initialised to run. These are described below.

Periods of the day

Each school provided the bell times for the start of the school day, beginning of recess, end of recess, beginning of lunch, end of lunch and end of the school day. These were used to define periods of the school day and were entered into the Excel Macro for each school. The Excel Macro generated data for 11 distinct periods (Table 3.3). Period 24 encompassed the 24-hour day from 4am-4am. Periods one and ten were considered to be sleeping time and were removed from analysis. Period two encompassed waking time until the beginning of the school day. Periods four and six encompassed recess and lunch-time breaks respectively. Periods three (mid-morning), five (late morning) and seven (early afternoon) defined class time periods. The start of period eight was defined by the last school bell and encompasses the after-school period until 6pm. The evening period (period 9) was defined for all schools as 6pm-10pm. For comparison purposes, the time of day periods on a weekend were matched to that of weekday although it is noted that it is unlikely that children's behaviour on a weekend day mirrors that of a structured school day.

Table 3.3 Segmented day time periods

Macro category	Time frame	Part of day
P24	4am-4am	Whole day
P1	4am-5.59am	Early morning
P2	6am-8.59am	Before school
P3	9am – start recess	Mid-morning
P4	Start recess – end recess	Recess
P5	End recess – start lunch	Late morning
P6	Start lunch – end lunch	Lunch
P7	End lunch – end school day	Early afternoon
P8	End school day – 6pm	After school
P9	6pm – 10pm	Evening
P10	10pm - 4am	Night time

Epoch length

Some evidence suggests there may only be a modest difference between data collected in 15- or 60-second epochs (Reilly et al. 2008); however, acknowledging that children's physical activity can be sporadic, a 15-second epoch length was selected to provide greater measurement sensitivity. LOOK data were collected in 5-second epochs and for consistency with Transform-Us! ActiGraph data were converted to 15-seconds prior to processing.

ActiGraph cut-points for sedentary time and MVPA

As discussed in section 2.4.2 studies of sedentary behaviour, that have used ActiGraph accelerometers, in young people have applied a range of cut-points. In this thesis, sedentary time was defined as ≤100 cpm (Evenson et al. 2006; Treuth et al. 2004; Trost et al. 2011); ≤25 counts/15-s epoch. MVPA (mins/day) was calculated using age adjusted cut-points (Freedson, Pober & Janz 2005), defined as ≥4 METs (Trost et al. 2011).

Non-wear time

Non-wear time was defined as 20 minutes or more of consecutive zero's as this definition is commonly used in pediatric populations (Cain et al. 2013) and wear time was calculated by subtracting non-wear time from the total waking day (i.e. 6am-10pm).

Data processing

Figure 3.1 illustrates the availability of ActiGraph and *activ*PAL™ files resulting when the files were created. ActiGraph data were downloaded using Actilife Monitoring System, Version 5.1 to produce .dat files. Thirty-seven ActiGraphs registered a malfunction when the files were created resulting in a final sample of 691 (Transform-Us!=482, LOOK=209) children for analysis. All *activ*PAL™ data were downloaded using PAL Technologies Professional Version 6.1.2 to produce files for analysis. Seventeen inclinometers registered a malfunction when the files were created resulting in a final sample of 188 children.

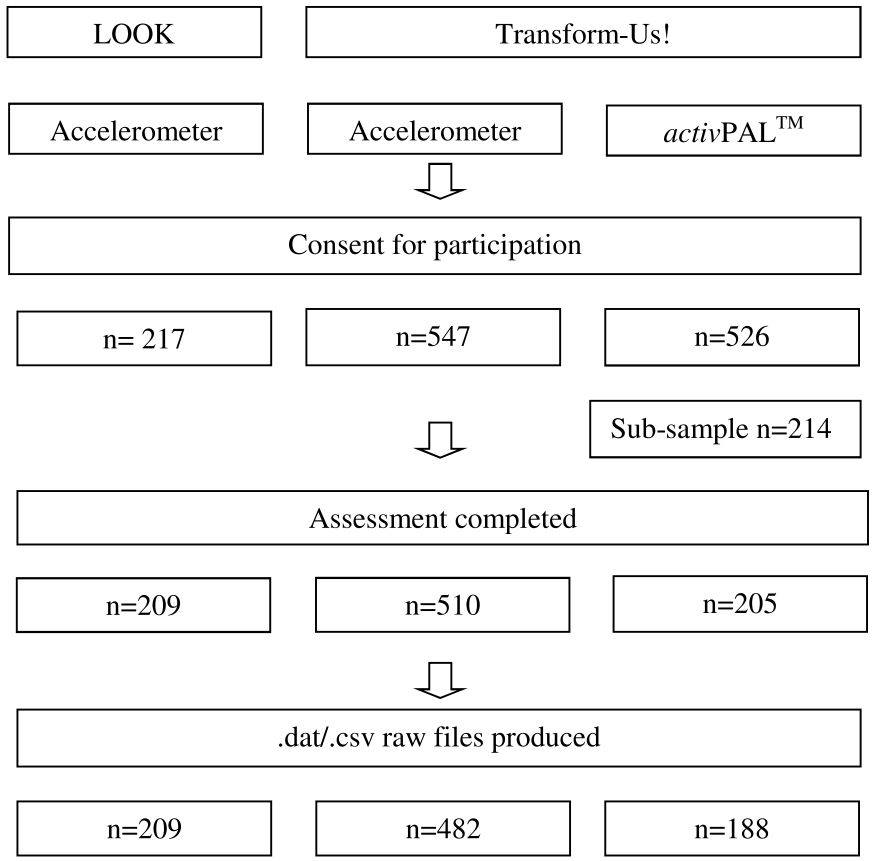

Figure 3.1 ActiGraph and activPAL™ data file availability

Sample size and wear time during a total day and periods of the day

Three valid weekdays (3 x ≥480 mins) and one weekend day (1 x ≥420 mins) was required to be included in whole day analyses (Mattocks et al. 2008). For the analysis of discrete periods of the day a criterion of 50% valid period wear time was applied (Hnatiuk et al. 2012; Ridgers et al. 2011). In line with the number of valid days criteria participants were required to have at least three valid periods on a weekday or one valid period on a weekend day (for example, to be included in the analysis of sedentary time patterns during recess on a school day children were required to have 3 valid recess periods of 50% wear time).

Table 3.4 provides a summary of the number of boys and girls who met the ActiGraph wear time criteria for a total weekday, weekend day and each of the periods examined. Of the children who wore an ActiGraph, 80% had at least three valid weekdays and 71% had at least one valid weekend day. In the main analysis, percentage of time spent sedentary was used because the periods differed in length (e.g. 20 minutes at break time and 180 minutes in the after school period). The corresponding wear time minutes for each period are therefore presented in Table 3.4 below to enable these data to be interpreted.

Table 3.4 Sample size and ActiGraph wear time (minutes) during a total weekday, weekend day and periods of the day among boys and girls

Period	n	Weekday Time (minutes)	n	Weekend day Time (minutes)
Total day*				
Boys	245	714.4 (73.5)	214	681.4 (103.3)
Girls	313	705.8 (72.1)	276	677.6 (102.8)
Early morning				
Boys	265	74.0 (28.3)	184	65.6 (38.9)
Girls	334	70.7 (27.8)	241	59.0 (34.3)
Mid-morning				
Boys	261	109.4 (13.1)	206	106.8 (17.8)
Girls	332	110.7 (14.3)	278	108.0 (20.0)
Morning break				
Boys	261	30.9 (7.4)	230	30.6 (7.1)
Girls	326	30.7 (7.5)	294	30.6 (7.3)
Late-morning				
Boys	260	97.8 (13.4)	228	98.3 (15.7)
Girls	326	99.7 (13.1)	299	100.5 (15.4)
Lunch				
Boys	257	48.6 (11.5)	230	50.0 (11.6)
Girls	323	49.2 (11.1)	299	49.5 (11.3)
Early afternoon				
Boys	263	76.5 (16.4)	232	76.2 (17.6)
Girls	323	74.9 (17.4)	299	75.0 (17.4)
After school				
Boys	246	154.6 (15.7)	234	155.1 (19.8)
Girls	306	152.9 (15.8)	300	153.7 (20.6)
Evening				
Boys	257	143.6 (48.4)	254	150.7 (64.4)
Girls	321	142.9 (45.6)	325	143.8 (66.5)

Wear time minutes represent mean (standard deviation, SD).
*The sum of the wear time in periods across the day does not equal the wear time for a total day because participants were able to be included in the analysis if they met the wear time criteria for the period but not the whole day or be included in the whole day analyses and excluded from one or more of the specific periods.

The *activ*PAL™ wear time criteria were matched to the ActiGraph wear time criteria, as described above. Table 3.5 provides a summary of the number of boys and girls who met the *activ*PAL™ wear time criteria for a total weekday, weekend day and each of the periods examined. Of the children who wore an *activ*PAL™, 74% had at least three valid weekdays and 70% had at least one valid weekend day. In the main analysis percentage of time spent sitting was used because the periods differed in length. The corresponding wear time minutes for each period are therefore presented in Table 3.5 below to enable these data to be interpreted.

Table 3.5 *activ*PAL™ wear time (minutes) during a total weekday, weekend day and periods of the day among boys and girls

Period	n	Weekday Time (minutes)	n	Weekend day Time (minutes)
Total day*				
Boys	59	679.3 (55.1)	59	621.1 (92.0)
Girls	80	666.4 (59.8)	73	641.7 (102.0)
Early morning				
Boys	70	60.6 (19.3)	49	52.1 (29.0)
Girls	101	60.4 (23.4)	75	48.1 (29.7)
Mid-morning				
Boys	62	102.6 (18.3)	52	101.8 (22.9)
Girls	95	103.1 (17.0)	76	104.9 (22.5)
Morning break				
Boys	64	28.7 (4.9)	57	27.8 (4.7)
Girls	94	28.5 (4.9)	74	28.7 (4.9)
Late-morning				
Boys	63	101.5 (13.5)	57	100.4 (17.5)
Girls	91	99.4 (13.2)	82	100.6 (16.9)
Lunch				
Boys	62	53.3 (8.9)	57	52.7 (9.3)
Girls	92	53.2 (9.1)	76	52.4 (9.8)
Early afternoon				
Boys	61	71.4 (15.7)	55	69.5 (17.0)
Girls	89	70.1 (18.2)	77	67.1 (18.6)
Late afternoon				
Boys	60	141.2 (10.9)	60	138.2 (20.2)
Girls	79	141.0 (13.3)	78	134.8 (21.8)
Evening				
Boys	68	122.2 (47.5)	60	134.9 (53.5)
Girls	88	120.3 (40.8)	87	124.0 (62.8)

Wear time values represent mean (standard deviation, SD).
*The sum of the wear time in periods across the day does not equal the wear time for a total day because participants were able to be included in the analysis if they met the wear time criteria for the period but not the whole day or be included in the whole day analyses and excluded from one or more of the specific periods analysis.

3.8.2 Bouts and breaks in sedentary and sitting time

Bouts

The measurement of sedentary bouts and associations with health is an emerging domain of sedentary behaviour research and limited evidence is available to guide the appropriate bout length/s that need to be examined. Thirty minutes represents the average length of children's TV programmes and was therefore initially selected as the maximum uninterrupted bout length. The shortest bout length was set at 2-5 minutes and additional bout lengths were calculated in increments of 5 minutes (i.e. 5-10, 10-15, 15-20 and 25-30 minutes). When bouts were examined in these lengths, the frequency of bouts longer than 15 minutes (i.e. 15-20, 20-25 and 25-30 minutes) was too small to be meaningful in 5 minute increments. Therefore it was decided to use 15 minutes as the cut-off for bout lengths in increments of 5 minutes and define the final category as encompassing uninterrupted time of 15 minutes or longer. Data were collected in 15-second epochs. Therefore, the bout lengths used in subsequent analyses are 2-4.75 minutes, 5-9.75 minutes, 10-14.75 minutes and ≥15 minutes. However, for interpretation bouts are presented as 2-5 minutes, 5-10 minutes, 10-15 minutes and ≥15 minutes.

A sedentary time bout was considered to have commenced when a full 15-second epoch of ≤25 counts was recorded and finished when the counts exceeded 25 counts for more than a 15-second epoch. A sitting bout was considered to have commenced when a complete 15-second epoch identified sitting as the posture. The sitting bout ended when the child transitioned to an upright posture.

As described in Chapter 2, previous studies have allowed for a ‘forgiveness rule’ of 20%. However, no forgiveness or tolerance was applied to the data management protocol for this doctoral thesis because in order to identify the threshold at which sedentary bouts are biologically meaningful, it is necessary to isolate uninterrupted sedentary time.

Breaks

A sedentary break was defined as an interruption in sedentary time in which the accelerometer counts changed from ≤25 counts/15s to >25 counts between epochs. A sit-to-stand transition was defined as the transition from sitting/lying to standing or stepping.

For illustrative purposes, an example of the determination of bouts and breaks is provided in Figure 3.2 for ActiGraph data and Figure 3.3 for *activ*PAL™ data.

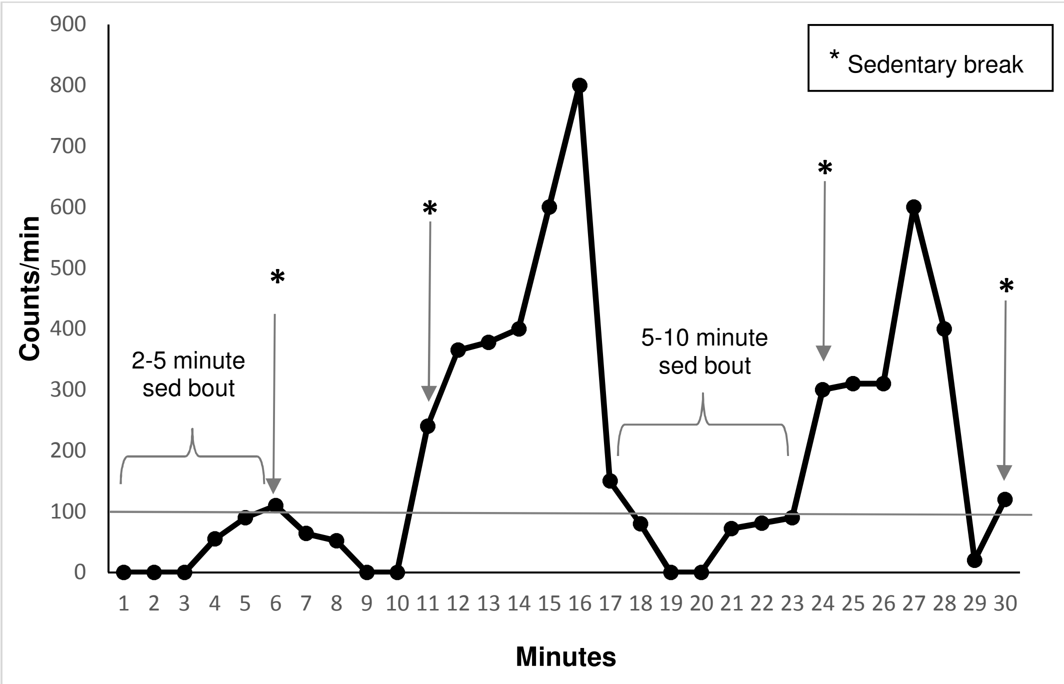

Figure 3.2 **Illustrative example of bouts and breaks in sedentary time (per 60 second epoch)**

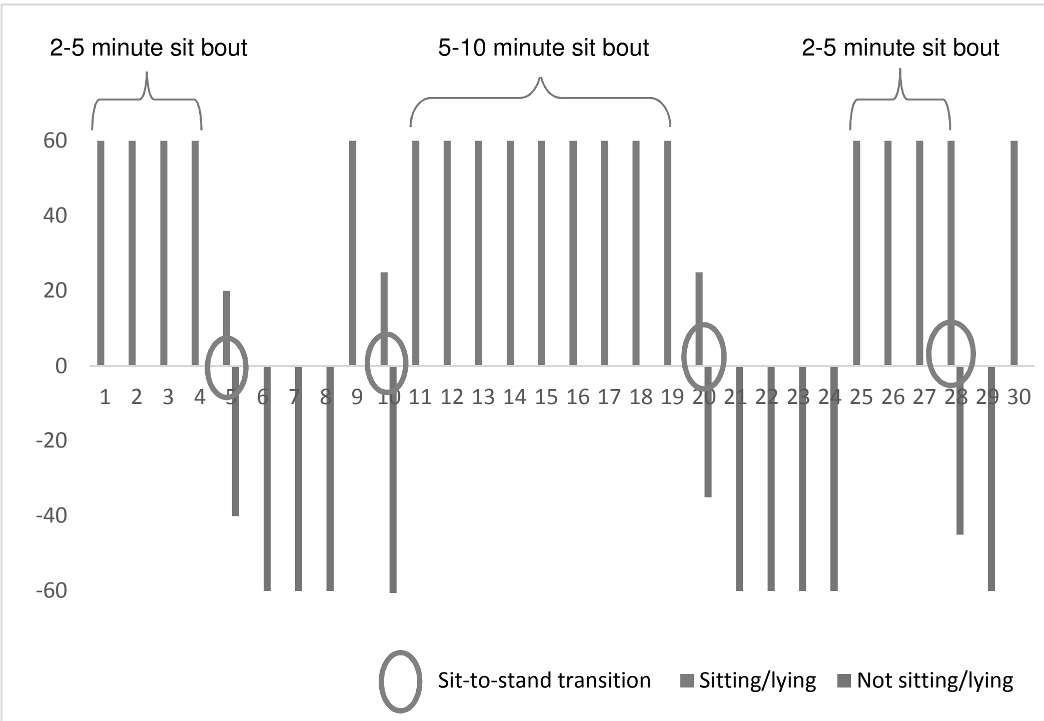

Figure 3.3 **Illustrative example of bouts of sitting time and sit-to-stand transitions (per 60 second epoch)**

3.8.3 Parent/carer survey data

In both Transform-Us! and LOOK all returned surveys were coded according to a pre-specified coding protocol. Surveys were then scanned so as to provide an electronic and hard copy record for each survey. The hard copies of the surveys were then sent to a data entry company. Data were transferred to SPSS for cleaning purposes. The cleaning process involved two stages. Firstly, data were checked for obscure values, missing values and values that did not fall within the expected range. Issues identified were resolved by the project manager. A complete data set was saved in SPSS and Excel, and access to the data sets were obtained by written request.

Diet energy density

As described in section 3.7.5, question 32 (a-f) asked the parent to report how frequently in the past month the child consumed six different types of energy dense foods (salty snacks, chocolate and sweets, cakes, pastries, fast food and chips). Responses for food items ranged, on a monthly nine point scale, from 'Never or less than once a month' = 1 to '6 or more times per day' = 9. Questions 35 and 36 obtained information on the usual daily frequency of fruit juice and soft drink consumption respectively. Responses for beverage items ranged, on a daily eight point scale, 'My child does not drink fruit juice' = 1 to '6 or more times a day' = 8. The sum of the scores was calculated to provide a total diet energy density score. The diet energy density score has been used in previous studies (Jackson et al. 2008) and has acceptable reliability (Campbell, Crawford & Ball 2006).

In the LOOK study, parents reported the child's consumption of takeaway and fast food, soft drink and sweetened juices in a normal week using a four point scale for fast food ('never' = 1 to '3 or more' = 4) and soft drink and sweetened juices ('none' = 1 to 'more than 7'). The sum of the scores were calculated to provide a total diet energy density score. In both studies, a higher score indicated a higher energy density of the diet.

3.8.4 Anthropometric and health measures

Data from the record sheets and pathology results were entered by research staff into a customised data base. The data were then exported to Excel to undertake the first of two data cleaning steps. Data were checked for obscure values, missing values and values that did not fall within the expected range. All unexpected values were cross checked against the data record sheets and pathology results and any identified issues were resolved by the project manager.

Definitions of risk for boys and girls were identified for blood pressure, cholesterol and lipids that encompass the age range of the cohort included within this thesis (i.e. 7-12 years). These are described below.

Weight status

BMI was calculated as kg/m^2 and normal weight, overweight and obesity were classified by international age specific cut-points for boys and girls (Cole et al. 2000). Australian percentile curves for waist circumference (Eisenmann 2005) were utilised to determine age and sex specific waist circumference percentile. A waist circumference $\geq 90^{th}$ percentile was used to classify obesity as recommended by the IDF for children aged six to less than 10 years and 10 to 16 years (Zimmet et al. 2007). Overweight was defined as a waist circumference ≥75th percentile but less than the 90th percentile (Savva et al. 2000).

Blood pressure

Blood pressure reference values do not currently exist for Australian children. Therefore, the percentiles for elevated blood pressure and hypertension defined by the National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents were used (National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents 2004, 2007). These percentiles are typically adopted in the literature for the classification of age and height specific blood pressure percentile in boys and girls. Normal blood pressure was determined as SBP and DBP <90th percentile, high blood pressure was defined as SBP and/or DBP ≥90th percentile but less than the 95th percentile, and hypertension was defined as SBP and/or DBP ≥95th percentile (National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents 2004, 2007). It should be noted that because clinical diagnosis of hypertension requires multiple measurements on several occasions the studies in this thesis were not diagnostic and only described the proportion of children with SBP and/or DBP ≥90th percentile but below the 95th percentile and the proportion of children with SBP and/or DBP ≥95th percentile (National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents 2004).

Lipids and cholesterol

Previous definitions of risk for lipid and cholesterol measures have not been age and sex specific (American Academy of Pediatrics 1992, 1998; Kavey 2003) despite evidence that lipid concentrations are related to age (Hickman 1998) and sex (Labarthe, Dai & Fulton 2003). To maintain consistency with utilising age and sex percentile cut-points for waist circumference and blood pressure, the current study adopted age and sex specific percentile cut-points for TC, HDL-C, LDL-C and TG (Daniels & Greer 2008) which were recommended to replace the 1998 American Academy of Pediatrics policy statement “Cholesterol in Childhood” (American Academy of Pediatrics 1998). At risk categories were determined as cholesterol (total cholesterol and LDL-C) or lipid (triglycerides) levels $\geq 90^{th}$ percentile and HDL-C below the 10^{th} percentile (Daniels & Greer 2008).

Clustered CVD risk score

Based on previous cardio-metabolic risk score methodologies (Andersen et al. 2006; Ekelund et al. 2006; Resaland et al. 2010), a continuously distributed clustered CVD risk score was derived using the values of SBP, DBP, LDL-C, HDL-C, TG and WC, expressed as z-scores. As HDL-C is inversely related to CVD risk it was multiplied by -1. The z-score for each measure was calculated as the number of standard deviation (SD) units from the sample mean after normalisation of the variable (Z = [value-mean]/SD). All standardised scores were summed to create a clustered CVD risk score with a higher score indicating a higher level of risk.

3.9 Data analyses

All analyses were undertaken with Stata/SE version 12 (StataCorp 2011) or SPSS version 21 (SPSS 2008). Specific data analysis methods are provided in the results chapters (Chapters 4-10).

3.10 Conclusion

This chapter has outlined the methodology of the Transform-Us! and LOOK studies. Specifically it has described the aim, study design, measures, data collection and data management procedures of these studies that follow in subsequent chapters.

Chapter 4
Prevalence of screen-based behaviours among primary school children across weekdays and weekend days

4.1 Introduction

Screen-based behaviours (SBBs) are the main component of children's sedentary leisure-time (Carvalhal et al. 2006; Martinez-Gomez, Tucker, et al. 2009) and several countries have implemented recommendations to limit recreational screen time (External working group under the National Board of Health 2003; National Heart Foundation of New Zealand 2004; Tammelin et al. 2007; The Department of Health and Children 2009; Tremblay, Leblanc, Janssen, et al. 2011). For example, in Australia the recommendation is that children should not engage in more than two hours a day using electronic media for entertainment purposes (The Department of Health 2014). However, population surveys have found that between 40 and 80% of young people are exceeding these recommendations (Australian Bureau of Statistics 2013b; Jago et al. 2008; Mitchell et al. 2009; Sisson et al. 2009).

Evidence of the amount of time children spend in screen time is largely derived from studies of TV viewing (Clark et al. 2011) or a total screen time measure, encompassing TV viewing, playing e-games and/or using a computer. A total screen time measure is important for monitoring compliance with public health recommendations at the population level. However, in order to effectively intervene information is needed regarding the types of different SBBs children are engaging in, when these behaviours are most prevalent (weekdays compared to weekend days), and how this may differ between boys and girls.

4.2 Aim

The aim of this chapter is to describe the prevalence of different types of SBBs and total screen time on weekdays and weekend days among Year 3 boys and girls.

4.3 Methods

4.3.1 Procedures

The current study utilised baseline data from a randomly selected sample of Year 3 Australian children enrolled in one of 20 schools in the Transform-Us! study. Time spent in SBBs (TV viewing, e-games and computer use) and the age (birth date) and sex of the child were obtained by parental proxy-report (described in section 3.7).

4.3.2 Data management

The management of the screen time data is described in detail in section 3.7.3 and 3.8.3, and summarised below.

Briefly, the question relating to screen time (Question 21; Appendix C.3) obtained information on the time spent in TV viewing, sedentary e-games and computer use. The parent was asked to circle “yes” or “no” to indicate if their child usually participated in each of the different SBBs and then to write the total amount of time usually spent in that behaviour from Monday to Friday and Saturday to Sunday. The total for Monday to Friday was divided by five to obtain an average weekday amount and the total for Saturday and Sunday was divided by two to obtain an average weekend day amount. A weekly average was calculated as the sum of these two figures. TV viewing, playing e-games and using a computer were treated as separate behaviours and combined to create an estimate of overall total screen time.

4.3.3 Data analyses

Analyses were undertaken with Stata/SE version 12. The distribution of each of the outcome variables was assessed. As data were normally distributed, independent t-tests were undertaken to determine differences between boys and girls in the time (minutes) spent engaged in different SBBs and total screen time (i.e. the sum of TV viewing, e-games and computer use) on weekdays and weekend days. Paired t-tests were undertaken to determine differences between weekday and weekend day time spent in each of the SBBs and total screen time.

Children were required to have a complete data set for each of TV viewing, e-games and computer use on weekdays and weekend days to calculate total screen time and be included in analysis.

4.4 Results

4.4.1 Family demographics

Table 4.6 describes the demographic characteristics of the families that participated in the Transform-Us! study. A total of 433 parents provided complete data for children's TV viewing, e-games and computer use. It was predominantly the mother or female carer of the child who completed the questionnaire (88%) and approximately half (51%) of these women were aged between 30 and 49 years. The majority of the children in the study were from dual parent families (85%). Approximately two-thirds of the primary parent/carers of the children were born in Australia (63%) and English was the primary language spoken at home in most families (88%). Just under half (47%) of the primary carers reported to have completed a university qualification and 57% were in full-time or part-time employment.

Table 4.6 Demographic characteristics of children's families (n=433)*

Characteristic	Frequency (n)	Percent (%)
Relationship of respondent to child participant		
Mother/female carer	381	88
Father/male carer	1	< 1
Grandparent	47	11
Other	4	1
Age (mean = 39.3)		
20-29 years	221	51
30-49 years	200	46
50+ years	8	2
Parent marital status		
Married/defacto	392	91
Separated/divorced	30	7
Other	10	3
Parent place of birth		
Australia	271	63
UK or Ireland	17	4
Germany	4	< 1
New Zealand	11	3
Vietnam	9	2
Poland	6	1
Other	115	27
English speaking household		
Yes	379	88
Parent level of education		
Primary school or some high school	65	15
Completed high school	110	25
University, technical or tertiary qualifications	256	59
Parent employment		
Full-time or part-time employed	250	57
Home duties full time	142	33
Other	36	8

*Data from Transform-Us! parent/carer questionnaire. N=433; not all percentages are equal to 100 due to rounding or missing data.

4.4.2 Proportion of boys and girls exceeding Australian screen time recommendations

Boys compared to girls

There was no difference between boys and girls in the percentage who exceeded screen time recommendations on a weekday (Figure 4.4; boys 44%, girls 40%). However, a significantly greater percentage of boys (82%) exceeded screen time recommendations compared to girls (74%) on weekend days (p<0.05).

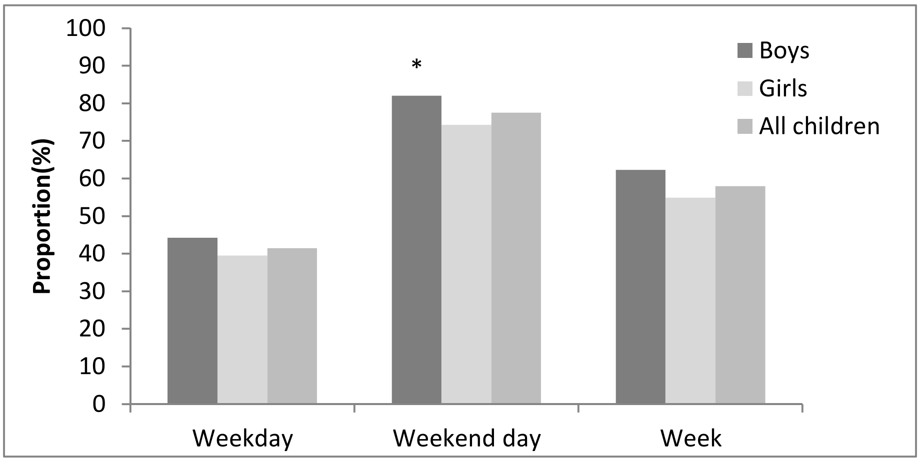

Figure 4.4 Differences in the percentage of boys and girls exceeding screen time recommendations on weekdays and weekend days

* p<0.05 for differences between boys and girls

Weekday compared to weekend day

A higher percentage of both boys and girls exceeded screen time recommendations on weekend days compared to weekdays (Figure 4.5; p<0.001).

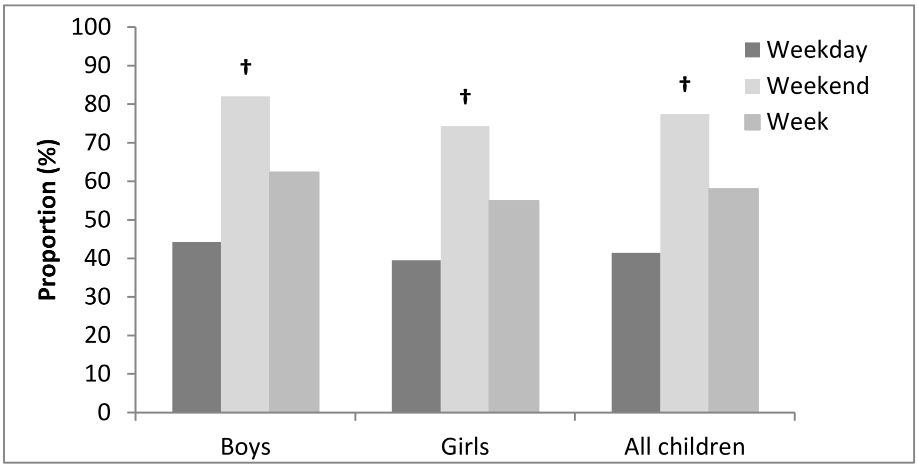

Figure 4.5 Percentage of boys and girls exceeding screen time recommendations on an average weekday, weekend day and overall day

† p<0.001 for differences between weekdays and weekend days

4.4.3 The contribution of TV, e-games and computer use to total screen time

As shown in Figure 4.6, TV was the largest contributor to both boys' (69%) and girls' (76%) screen time on weekdays and on weekend days (boys 60%, girls 67%; p<0.001). The proportion of screen time spent playing e-games was higher for boys (18%) compared to girls (11%) on both weekdays and weekend days (boys 28%, girls 17%). Computer use comprised the smallest proportion of total screen time and was similar for boys and girls on weekdays (13.5 and 13.2% respectively) and weekend days (12.3 and 15.1% respectively).

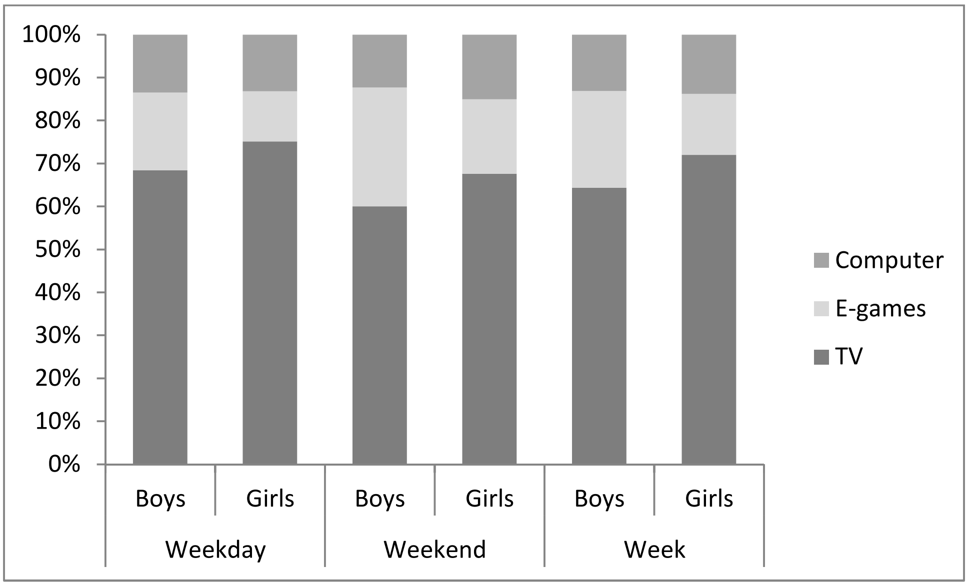

Figure 4.6 Contribution of TV, e-games and computer use to boys' and girls' total screen time on an average weekday, weekend day and overall weekly day

4.4.4 Average time spent in specific SBBs on weekdays and weekend days among boys and girls

Figure 4.7 (a-d) shows the amount of time spent watching TV, playing e-games, using a computer and total screen time among boys and girls on weekdays and weekend days. There was no difference between boys and girls in the amount of time spent watching TV or using the computer on weekdays or weekend days. However, boys spent significantly more time playing e-games compared to girls on weekdays ($p<0.001$) and weekend days ($p<0.001$). Boys' overall total time spent in screen use was significantly higher than girls' on weekend days ($p<0.001$) but not weekdays. All children spent significantly more time watching TV, playing e-games, using a computer and in total screen time on weekend days compared to weekdays ($p<0.001$).

a b

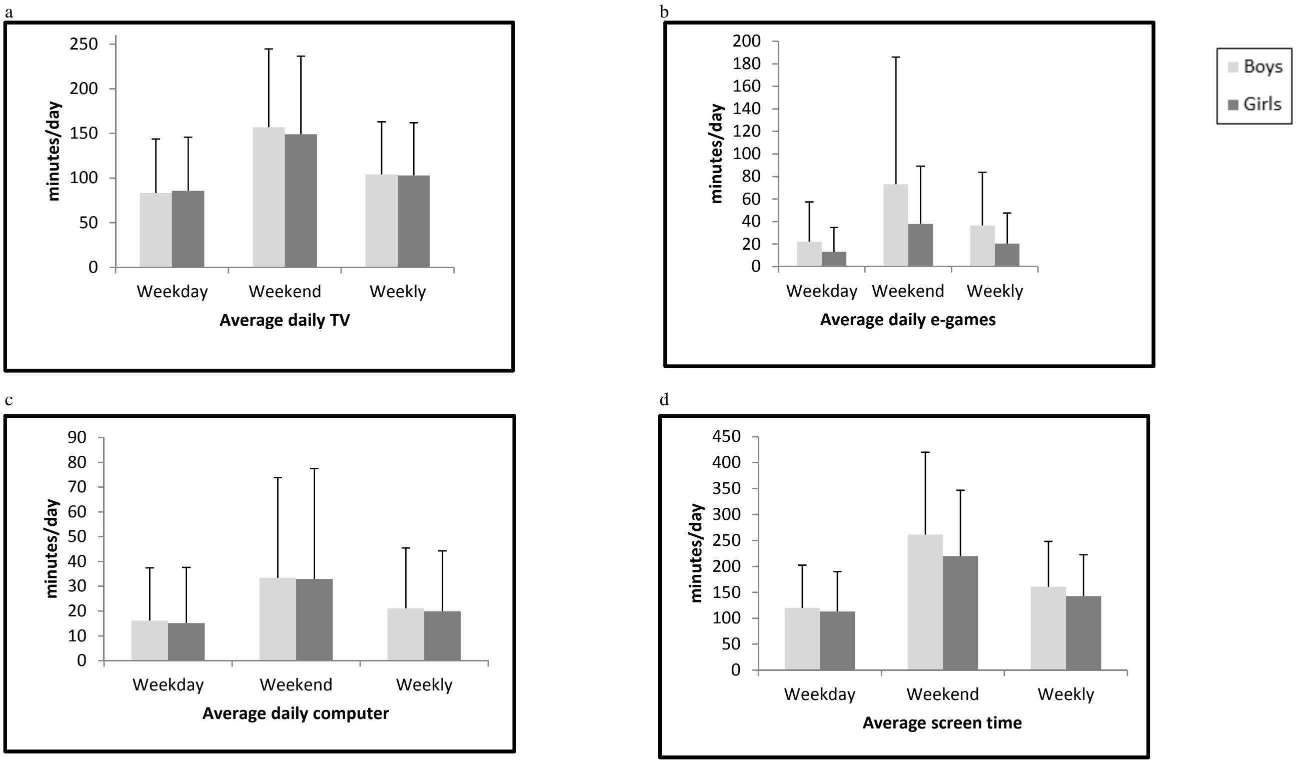

Figure 4.7 TV viewing (a), e-games (b), computer use (c) and total screen time (d) in boys and girls on weekdays and weekend days.
All differences between boys and girls weekday and weekend day time spent in TV viewing, e-games, computer use and total screen time were significant at $p<0.001$

4.5 Discussion

The current study described the prevalence of specific SBBs and total screen time among a sample of Year 3 Australian boys and girls. The main findings were that: A high percentage of children exceeded screen time guidelines in the current sample and the percentage was higher on weekend days compared to weekdays. The percentage of boys who exceeded screen time guidelines as well as the amount of time spent in total screen time was higher on weekend days compared to girls. TV viewing comprised the highest percentage of total screen time, although boys engaged in a higher percentage of time playing e-games compared to girls on both weekdays and weekend days.

Among the current sample of Year 3 Australian children approximately 55% of girls and 65% of boys exceeded screen time recommendations on an average day (i.e. across the total week). This finding is similar to population estimates in Australia (Australian Bureau of Statistics 2013a) and Canada (Active Healthy Kids Canada 2013). However, cross-sectional prevalence studies of primary school age children in Europe (Jago et al. 2008) and the US (Sisson et al. 2009) have reported lower levels of children exceeding screen time recommendations compared to the current study. An important consideration of those studies is the classification of screen time, whereby the UK study only measured TV viewing and the US study did not include e-games. Subsequently, the definition of screen time in those studies includes fewer types of specific SBBs and total screen time is likely to be underestimated. In order to compare and monitor population trends a consistent definition of screen time is needed.

A lower percentage of boys and girls complied with screen time recommendations on weekend days (18% and 26% respectively) compared to weekdays (56% and 61% respectively). Similarly the findings from a study of 3-10 year old Portuguese children (Canadian Society for Exercise Physiology 2011) and 5-6 year old children in the UK (Bull 2010) reported lower compliance with screen time recommendations on weekend days compared to weekdays. It is not surprising that compliance with screen time recommendations was lower on weekend days when children are likely to have greater discretionary time. While it may therefore seem intuitive that interventions to reduce screen time would be most effective on weekend days it is concerning that a high percentage of children exceeded screen time guidelines on weekdays when discretionary leisure time is limited. Furthermore, the amount of time spent in specific SBBs on a weekend day was approximately double that of a weekday yet there are five weekdays across the week. Therefore a child who spends two hours engaged in specific SBBs on a weekday and four hours on a weekend day spends a total of ten hours across weekdays and eight hours across weekend days in specific SBBs. Interventions that target both weekday and weekend day screen time are needed.

Similar to reports in previous cross-sectional studies in this age group (Verloigne et al. 2013; Kiltsie et al. 2013), TV viewing comprised the greatest amount of boys' (69%) and girls' (76%) total screen time and computer use the smallest amount (13%). While the percentage of time engaged in TV viewing was lower in boys, this is likely to be explained by the higher percentage of time spent playing e-games in boys compared to girls. This finding reflects that of a recent cross-sectional study, utilising data from the SPEEDY population study in the UK

(Kiltsie et al. 2013). In that study, boys spent 255 minutes/week and girls 75 mins/week playing e-games. The higher levels of e-game usage among boys, suggests this may be an important behavioural target for interventions. Furthermore, it highlights the importance of assessing differences between boys and girls preferences for screen-based pursuits as this may have important relevance to interventions that aim to reduce sedentary time. Interestingly, in the Transform-Us! study the percentage of total screen time spent in e-games changed more so in boys than girls on a weekend day compared to a weekday with approximately 10% more time spent in e-games on weekend days. This may reflect parental restrictions on e-games usage on weekdays as well as the overall greater preference for playing e-games among boys.

Strengths and limitations

Several considerations are important in the interpretation of the study findings. A parent proxy-report questionnaire was used to ascertain usual time spent in specific SBBs on weekdays and weekend days. Therefore, time spent in specific SBBs may have been underestimated as parents may underestimate children's screen time, particularly if the child has a TV in their bedroom (Jago et al. 2008; Marshall & Welk 2008). However, the questions have been validated (Salmon et al. 2008) and self-report questionnaires are not recommended in the age group of the current study, i.e. children under the age of 10 years (Trost 2007). A further consideration is the restrictions of SBBs to TV viewing, e-games and computer use which may not capture the wide range of electronic media options that are available to children. It is an important strength of the current study that time spent in SBBs was assessed separately for boys and girls on weekdays and weekend days as the findings provide valuable information as to opportunities to maximise interventions that aim to reduce children's screen time.

Conclusion

The findings from the current study support widespread concern that children engage in high levels of screen time on weekdays and weekend dayss. While TV viewing comprised the greatest percentage of children's total screen time, the higher levels of e-games in boys suggests e-games may be a particularly important behavioural target for boys in this age group. However, given the potential for e-games to increase light and moderate intensity activity (Le Blanc 2013) it is not known whether time spent in e-games is detrimental or beneficial to health (if it is replacing sedentary time). Furthermore, although computer use was low in this cohort of 7-10 year olds that is not to say it won't be more prevalent in older youth. Further research is needed to ascertain the relevance of different SBBs to CVD health, in particular TV viewing and playing e-games. In addition children have numerous opportunities to be sedentary, yet self- and proxy-report questionnaires tend to be limited to the assessment of single behaviours. Objective measures which can capture the total time spent sedentary and identify when high periods of sedentary behaviour are occurring will be important for future studies of children's sedentary behaviour.

Chapter 5
Prevalence and patterns of objectively measured sedentary time among 7-12 year olds

5.1 Introduction

Children have numerous opportunities to be sedentary throughout the day by way of transport, the structured school environment and leisure-time pursuits. As described in the previous chapter (Chapter 4), time spent in specific SBBs, in particular TV viewing, is considered to be the dominant leisure-time sedentary behaviour. Therefore, information on sedentary time is typically derived from reported measures of time spent in TV viewing or total screen time (Clark et al. 2011). While questionnaires provide important contextual information about what children are doing when they are sedentary, the assessment of single behaviours is unlikely to capture all of children's sedentary time (Verloigne et al. 2013). Furthermore, an inherent limitation of questionnaires is the bias associated with recalling time spent in specific behaviours (Trost 2007).

Accelerometers have become increasingly popular in sedentary behaviour research as they can measure counts within a defined epoch to objectively assess sedentary time (Cain et al. 2013). In addition, due to the time-stamped ability of accelerometers it is possible to define specific time frames of interest and measure the amount of time spent sedentary within those periods. Therefore, information on high and low periods of sedentary time can be identified which may be particularly useful in determining critical windows of opportunity within which to maximise the effectiveness of strategies to reduce children's sedentary time.

Some studies have examined hour-by-hour patterns of sedentary time in 9-10 year olds (Steele et al. 2010) and 8-11 year olds (Guinhouya et al. 2007) using accelerometers. However, this approach ignores potentially key periods for targeted intervention (e.g. class time and recess, or class time and home time). A recent study of 10-12 year olds (Abbott, Straker & Mathiassen 2014), examined sedentary time during school hours compared to non-school hours and weekend days. However, sedentary patterns during specific times of the school day (e.g. class time compared to break time) or outside school hours was not assessed in that study. One study has examined periods across the school day in youth (Bailey et al. 2012); however, the results are limited to 10-14 year olds in the UK. Therefore, the current evidence is not sufficient to inform specific windows of opportunity in which strategies and interventions to reduce sedentary time may have the greatest effectiveness.

In addition to total sedentary time, emerging evidence from studies of adults suggests the way in which sedentary time is accumulated (i.e. bouts and breaks) may be important for cardiovascular health. For example, observational (Healy, Dunstan, et al. 2008; Healy et al. 2011) and experimental studies (Dunstan, Kingwell, et al. 2012) have found significant and positive beneficial associations between increased breaks in sedentary time and CVD risk factors. It may therefore be an important aspect of future health promotion policy and interventions to gain a better understanding of not just when children accumulate sedentary time but how that time is accumulated such that periods of unbroken sedentary time can be targeted.

5.2 Aims

The aims of this chapter are to:

1. Examine the objectively measured patterns of sedentary time across waking periods on weekdays and weekend days; and
2. Determine the frequency of breaks in and bouts of sedentary time among a sample of 8-12 year old Australian boys and girls.

5.3 Methods

5.3.1 Procedures

The current study utilised pooled accelerometer baseline data of Year 3 Australian primary school children enrolled in the Transform-Us! study (Salmon et al. 2011) and Year 5 Australian children enrolled in the LOOK study (Telford et al. 2009). The ActiGraph data collection procedures are described in detail in section 3.7.1. Briefly, children from both studies were fitted with an ActiGraph accelerometer (GT3X in Transform-Us! and GT1M in LOOK participants) by trained research assistants and were instructed to wear the monitor for eight consecutive days on a belt positioned over the right hip and to remove it during sleep time and water-based activities, such as swimming and bathing as well as contact sports if needed.

Family demographic information, including parent age, education and country of birth was obtained by a questionnaire which was completed by a parent or carer of the child in Transform-Us! (Appendix C.4) and LOOK (Appendix D.3 and D.4).

5.3.2 Data management

The management of the ActiGraph data is described in detail in section 3.8.1 and summarised below.

Accelerometer data reduction

Briefly, accelerometer data were downloaded in 15-second epochs using Actilife Monitoring System, Version 5.1. Non-wear time was defined as 20 minutes or more of consecutive zeroes (Cain et al. 2013). Three valid weekdays (3 x ≥480 mins) and one weekend day (1 x ≥420 mins) was required to be included in whole day analyses, and three valid weekday or one valid weekend day period (50% wear time) to be included in temporal patterns analysis (Hnatiuk et al. 2012; Ridgers et al. 2011).

Sedentary time variables

The raw files were processed with a customised Excel Macro programme to generate sedentary time, breaks in sedentary time and bouts of sedentary time on weekdays and weekend days. Sedentary time was defined as ≤100 cpm (Ridgers et al. 2012; Trost et al. 2011). As described in section 3.8.2, bouts that lasted 2-5, 5-10, 10-15 and ≥15 minutes were examined. The first complete 15-second epoch of sedentary time (i.e. ≤25 counts/15s) defined the beginning of a sedentary bout and the last consecutive sedentary epoch defined the end of a sedentary bout. A sedentary break was defined as an interruption in sedentary time in which the accelerometer counts changed from ≤25 counts/15s to >25 counts within the epoch.

Periods of the day

As described in section 3.8.1 and shown Table 3.3, discrete periods of the day were generated on the basis of school bell times.

5.3.3 Data analyses

Analyses were undertaken with SPSS version 21 (SPSS Inc., Chicago, IL.). Chi-square tests and independent t-tests were used to explore differences in family demographics and child characteristics for the Transform-Us! and LOOK study groups. For further analysis, data were combined and the distribution of each of the outcome variables was assessed for normality. Analysis of covariance (ANCOVA) was used to determine differences between boys and girls in the percentage of time spent sedentary and the frequency of breaks in and bouts of sedentary time on weekdays and weekend days. Study group (i.e. Transform Us! or LOOK) and age were firstly included as covariates. Study group was not associated with sedentary time ($p>0.1$); however, age was associated with sedentary time and was therefore retained ($p<0.05$) in subsequent analyses. Paired t-tests were undertaken to determine differences between weekday and weekend day percentage of time, hours spent sedentary and the frequency of breaks in and bouts of sedentary time for boys and girls.

5.4 Results

5.4.1 Characteristics of the sample

As described in Table 5.7 approximately 83% of parents from Transform-Us! and 91% of parents from LOOK completed the questionnaire. In both study groups approximately three-quarters of parents were aged between 30 and 49 and a similar percentage were married. A higher percentage of parents from LOOK were born in Australia (63%) compared to the Transform-Us! sample (52%, $p<0.001$). A higher percentage of parents from Transform-Us! had completed a University degree ($p<0.001$). A higher percentage of parents from LOOK (75%) compared to Transform-Us! (50%) were either in part-time or full-time employment ($p<0.001$). The average age of children in LOOK was approximately 11 years and in Transform-Us! it was approximately 8 years ($p<0.001$). The average number of valid weekdays and weekend days (4.7 and 1.8 respectively) was similar between groups.

Table 5.7 Characteristics of the Transform-Us! and LOOK samples

	Transform-Us! (n=405)		LOOK (n=194)	
	Frq (n)	**%**	**Frq (n)**	**%**
Parent characteristics				
Relationship to child				
Mother/female carer	295	72.8	160	82.4
Father/male carer	32	7.8	16	9.1
Age				
20-39 years	170	52.5	71	40.7
40-49 years	149	36.8	93	47.9
50+ years	5	1.2	8	4.0
Marital status				
Married/defacto	298	73.6	146†	75.3
Separated/divorced	19	4.7	17	8.8
Other[a]	7	1.7	4	2.0
Country of birth				
Australia	211	52.1	122	62.9
Other[b]	115	28.4	25	12.9
Level of education				
University or tertiary	152	37.5	50**	25.8
Other[c]	170	42.0	94	48.5
Employment				
Full-time or part-time employed	202	49.8	145†	74.7
Home duties full-time	93	23.0	26	13.4
Other[d]	21	5.2	4	2.1
Child characteristics				
Sex (Male)	169	41.7	96	49.5
Age (mean, SD) in years	8.2 (0.5)		11.5 (0.5) †	
No. valid weekdays (mean, SD)	4.7 (1.0)		4.7 (0.8)	
No. valid weekend days (mean, SD)	1.8 (0.5)		1.8 (0.4)	

Not all frequencies equal to 405 (Transform-Us!) and 194 (LOOK) due to missing parent survey data.

'Other' includes: [a] widowed; [b] UK or Ireland, New Zealand, Thailand, Germany; [c] Primary school, technical or trade; [d] miscellaneous

* p<0.05; ** p<0.01; † p<0.001

5.4.2 Whole day percentage of sedentary time and breaks in and bouts of sedentary time

Table 5.8 describes the percentage of time the combined sample (Transform-Us! and LOOK) of boys and girls spent sedentary and the frequency of breaks in and bouts of sedentary time on a total weekday and weekend day.

Daily patterns of sedentary time – boys compared to girls

The percentage of time spent sedentary was significantly higher in girls compared to boys on weekdays ($p<0.05$), although the difference between boys and girls hours spent sedentary was not significantly different. The frequency of sedentary breaks was significantly higher in girls compared to boys on weekdays ($p<0.05$). On weekend days, the percentage of sedentary time was similar among boys and girls; however, the frequency of breaks in sedentary time was significantly higher in girls ($p<0.05$). There were no significant differences between boys and girls in the frequency of bouts on weekdays. On weekend days girls had a significantly higher frequency of 5-10 ($p<0.001$) and 10-15 minute bouts ($p<0.05$) compared to boys.

Daily patterns of sedentary time – weekday compared to weekend day

Girls spent significantly more time sedentary on weekdays compared to weekend days ($p<0.001$) yet had a significantly lower frequency of sedentary breaks on weekdays compared to weekend days ($p<0.001$). Both boys ($p<0.01$) and girls ($p<0.001$) had a higher frequency of 2-5 minute bouts on weekdays compared to weekend days. Girls had a higher frequency of 5-10 minute ($p<0.001$) and 10-15 minute bouts on weekdays ($p<0.05$) compared to weekend days.

Table 5.8 Total daily volume of sedentary time (hours), percentage of sedentary time and frequency of breaks in and bouts of sedentary time on weekdays and weekend days

	Weekday (n=558)				Weekend day (n=490)			
	All children	**Boys**	**Girls**	***p* for sex**	**All children**	**Boys**	**Girls**	***p* for sex**
Sedentary time								
Percentage	60.9 (6.1)	60.3 (6.2)	61.5 (6.1)	0.01	59.0 (9.1)	59.6 (9.2)	58.4 (8.9)†	0.32
Hours	5.7 (1.2)	5.6 (1.2)	5.7 (1.1)	0.11	6.3 (1.7)	6.4 (1.7)	6.2 (1.7)†	0.47
Breaks (Frq)	247 (47.3)	243.0 (46.1)	251.4 (48.5)	0.03	278.6 (71.2)	269.7 (68.3)†	287.4 (74.1)†	0.01
Bouts (Frq)								
2-5 mins	39.9 (7.0)	39.8 (7.0)	40.0 (7.0)	0.33	37.4 (10.0)	37.6 (10.1)**	37.2 (9.9)†	0.77
5-10 mins	12.6 (3.7)	12.6 (3.9)	12.5 (3.4)	0.84	12.2 (4.9)	12.9 (5.3)	11.4 (4.5)†	0.002
10-15 mins	3.1 (1.6)	3.1 (1.6)	3.1 (1.5)	0.75	3.2 (2.2)	3.4 (2.3)	2.9 (2.0)*	0.03
≥15 mins	1.4 (0.9)	1.4 (0.9)	1.4 (0.8)	0.56	1.7 (1.5)	1.7 (1.7)	1.6 (1.2)	0.54

Values represent mean (SD) determined by independent-samples t-test
Differences within sex between weekdays and weekend days determined by paired-samples t-tests and significance indicated by: * p<0.05; ** p<0.01; † p<0.001

5.4.3 Temporal patterns of sedentary time and breaks in and bouts of sedentary time in boys and girls

The results for the analysis of sedentary time and breaks in and bouts of sedentary time across periods of the weekday and weekend day in boys and girls are shown in Figures 5.8-5.13 with values presented as mean, 95% confidence intervals (CI). The corresponding tables of numerical data are presented in Appendix E.1.

Sedentary time - boys compared to girls

As shown in Figure 5.8, girls spent a significantly higher percentage of time sedentary compared to boys on weekdays during the early morning ($p<0.05$), mid-morning ($p<0.01$), morning break ($p<0.001$), late morning ($p<0.01$), lunch ($p<0.001$) and early afternoon ($p<0.01$) periods.

Sedentary time - weekdays compared to weekend days

Both boys and girls spent a significantly higher percentage of time sedentary during the mid-morning ($p<0.001$), late-morning ($p<0.001$) and early afternoon ($p<0.001$) time periods on weekdays compared to the equivalent time periods on a weekend day (Figure 5.8). However, on weekend days the percentage of time spent sedentary was significantly higher during the early morning ($p<0.001$), morning break, lunchtime ($p<0.001$) and late afternoon time periods (boys $p<0.01$, girls $p<0.05$).

Frequency of sedentary breaks - boys compared to girls

On weekdays boys had significantly fewer sedentary breaks during the morning break ($p<0.001$), lunch ($p<0.001$) and late afternoon periods ($p<0.001$) compared with girls (Figure 5.9). On weekend days boys had significantly fewer breaks during the weekday equivalent morning break period ($p<0.01$), late morning ($p<0.01$), early afternoon ($p<0.05$) and late afternoon ($p<0.01$) compared with girls.

Frequency of sedentary breaks - weekdays compared to weekend days

Boys had significantly fewer breaks in sedentary time on a weekday during the morning break ($p<0.001$), lunch ($p<0.001$) and the late afternoon period ($p<0.01$) compared to weekend days (Figure 5.9). However, on weekend days boys' frequency of breaks in sedentary time was lower during the early morning period ($p<0.001$), late morning ($p<0.05$) and early afternoon period ($p<0.001$) compared to weekdays. Among girls the frequency of sedentary breaks was lower during mid-morning ($p<0.05$), morning break ($p<0.001$), late morning ($p<0.01$), lunch ($p<0.001$), early afternoon ($p<0.05$) and the late afternoon period ($p<0.05$).

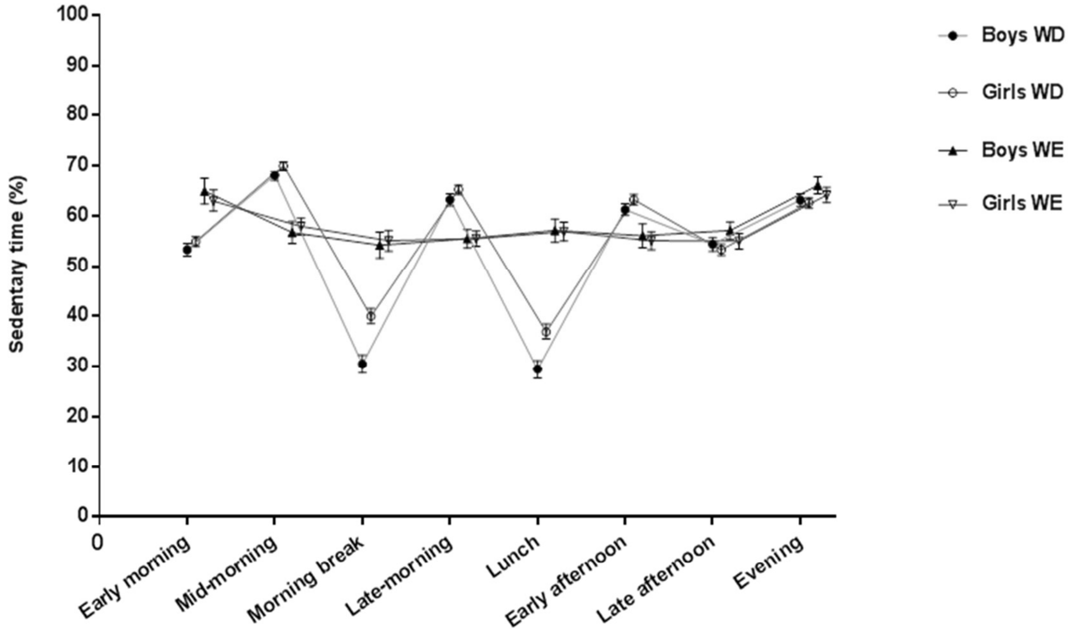

Figure 5.8 Percentage of time spent sedentary (mean, 95% CI) during weekday and weekend day periods in boys and girls

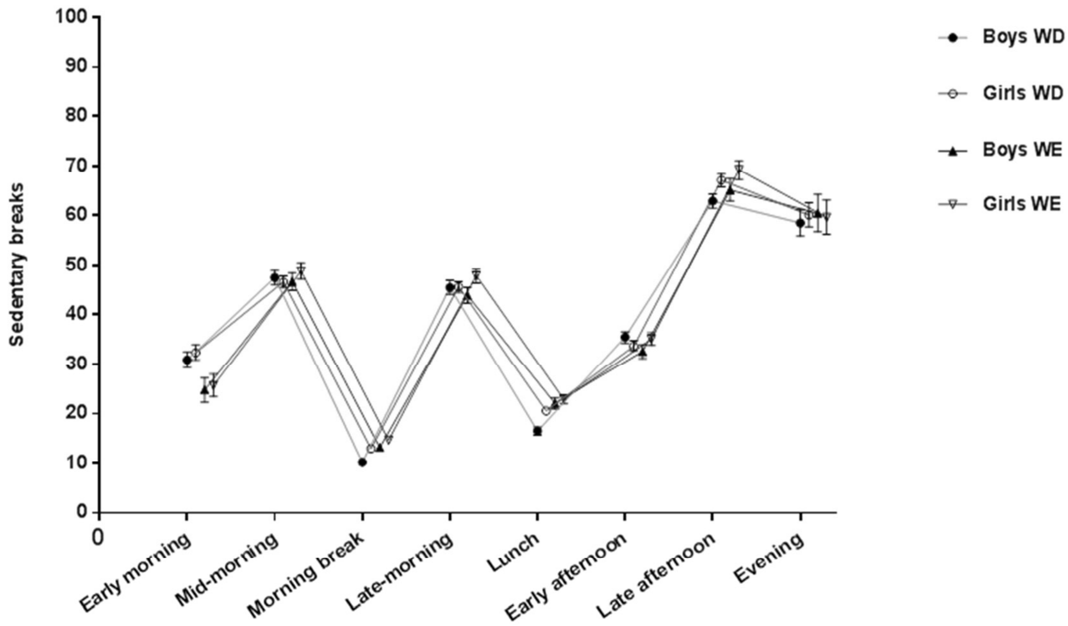

Figure 5.9 Frequency of sedentary breaks (mean, 95% CI) during weekday and weekend day periods in boys and girls

Frequency of 2-5 minute sedentary bouts - boys compared to girls

Figure 5.10 shows the frequency of 2-5 minute sedentary bouts in boys and girls on weekdays and weekend days. The frequency of 2-5 minute sedentary bouts was significantly higher among girls compared to boys on weekdays during the morning break and lunch time periods (p<0.001). There were no differences between boys and girls frequency of 2-5 minute sedentary bouts on weekend days during any of the periods.

Frequency of 2-5 minute sedentary bouts - weekday compared to weekend day

Both boys and girls had a higher average number of 2-5 minute sedentary bouts on weekdays during the mid-morning, late morning and early afternoon periods (p<0.001) compared to weekend days (Figure 5.10). Girls also had a higher frequency of 2-5 minute sedentary bouts during the early morning period on weekdays (p<0.01) compared to weekend days. During the morning break and lunchtime periods boys and girls had a higher frequency of 2-5 minute sedentary bouts on weekend days compared to weekdays (p<0.001) and for girls the frequency was also higher during the late afternoon period on weekend days (p<0.05).

Frequency of 5-10 minute sedentary bouts - boys compared to girls

Figure 5.11 shows the frequency of 5-10 minute sedentary bouts in boys and girls on weekdays and weekend days. The average frequency of 5-10 minute sedentary bouts was significantly higher among girls compared to boys on weekdays during the mid-morning period (p<0.05), morning break (p<0.05) and lunch time (p<0.01). Boys had a significantly higher average frequency of 5-10 minute sedentary bouts on an overall weekend day (*p*<0.01) and during the lunch (*p*<0.06) and late afternoon periods (*p*<0.05).

Frequency of 5-10 minute sedentary bouts - weekday compared to weekend day

The average number of 5-10 minute sedentary bouts was significantly higher on weekend days among boys during the morning break period (*p*<0.001), lunch (*p*<0.001), late afternoon (*p*<0.05) and evening (*p*<0.001) compared to weekend days (Figure 5.11). However, on weekdays the average frequency of 5-10 minute sedentary bouts was higher during the mid-morning (*p*<0.001) and late morning (*p*<0.01) periods, compared to weekend days. During periods of the weekend day the average frequency of 5-10 minute sedentary bouts was significantly higher during the early morning (*p*<0.05), morning break (*p*<0.001) and lunch (*p*<0.001) periods. On weekdays the average frequency of 5-10 minute sedentary bouts was higher during the mid-morning (*p*<0.001), late morning (*p*<0.001) and early afternoon (*p*<0.001) compared to weekend days.

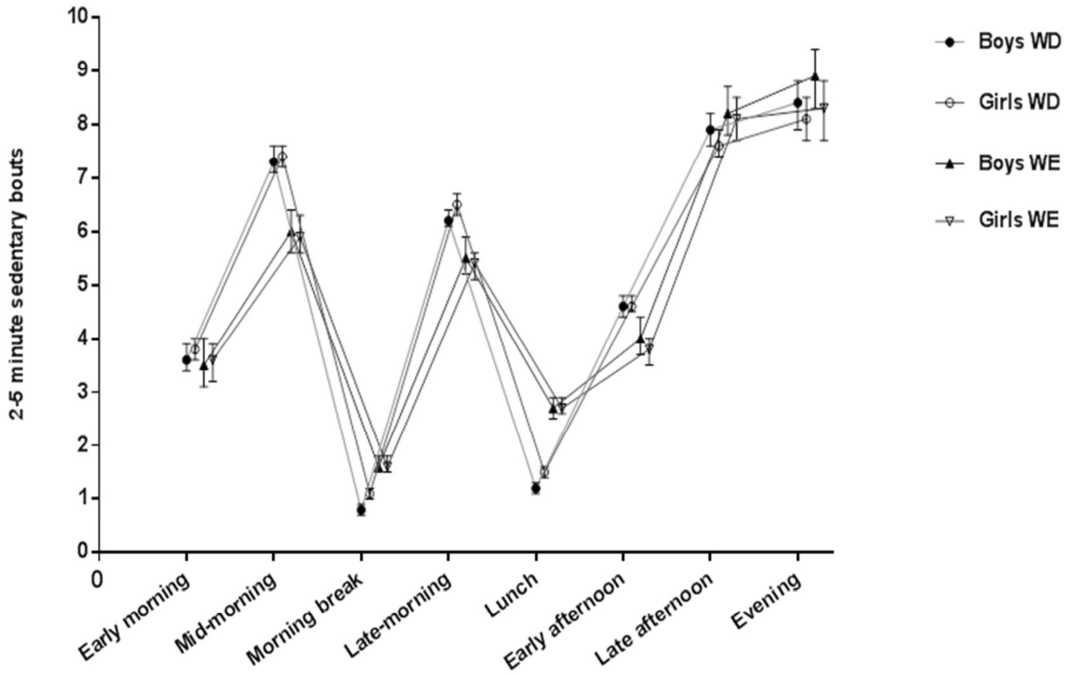

Figure 5.10 Frequency of 2-5 minute sedentary bouts (mean, 95% CI) during weekday and weekend day time periods in boys and girls

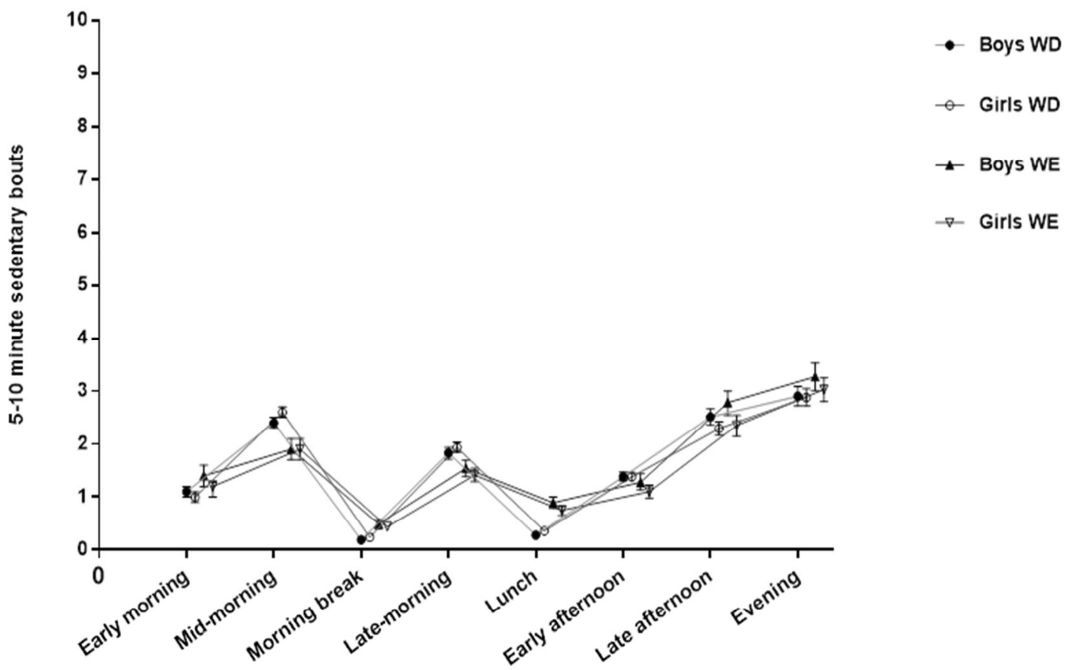

Figure 5.11 Frequency of 5-10 minute sedentary bouts (mean, 95% CI) during weekday and weekend day time periods in boys and girls

Frequency of 10-15 minute sedentary bouts - boys compared to girls

Figure 5.12 shows the frequency of 10-15 minute sedentary bouts in boys and girls on weekdays and weekend days. The frequency of 10-15 minute sedentary bouts was significantly higher among girls compared to boys on weekdays during the early morning ($p<0.05$), mid-morning ($p<0.01$), morning break ($p<0.05$) and late morning ($p<0.05$) time periods. Boys had a significantly higher average frequency of 10-15 minute sedentary bouts on a total weekend day ($p<0.05$) and in the early morning period ($p<0.001$) than girls.

Frequency of 10-15 minute sedentary bouts - weekday compared to weekend day

On weekdays boys had a higher frequency of 10-15 minute sedentary bouts during the mid-morning ($p<0.01$) and late morning ($p<0.05$) periods compared to weekend days (Figure 5.12). However, the frequency of 10-15 minute sedentary bouts was higher on weekend days during the early morning ($p<0.001$), morning break ($p<0.01$) and lunch ($p<0.001$) periods compared to weekend days. Among girls the frequency of 10-15 minute sedentary bouts was higher during a total weekday compared to a weekend day and during the mid-morning ($p<0.01$) and late morning ($p<0.05$) weekday periods. On weekend days the average frequency of 10-15 minute sedentary bouts was significantly higher during the morning break ($p<0.05$), lunch ($p<0.001$), early afternoon ($p<0.001$) and evening ($p<0.01$) periods on weekend days compared to weekdays among girls.

Frequency of ≥15 minute sedentary bouts - boys compared to girls

Figure 5.13 shows the frequency of ≥15 minute sedentary bouts in boys and girls on weekdays and weekend days. The frequency of ≥15 minute sedentary bouts was significantly higher among girls compared to boys on weekdays during the late morning (p<0.05) and late afternoon (p<0.05) periods. There were no differences between boys and girls average frequency of sedentary bouts ≥15 minutes on weekend days.

Frequency of ≥15minute sedentary bouts - weekday compared to weekend day

On weekdays compared to weekend days the frequency of ≥15 minute bouts was higher during the mid-morning period (p<0.001) among boys and girls (Figure 5.13). On weekend days however, the frequency of ≥15 minute sedentary bouts was significantly higher during the early morning period (p<0.01), lunch (p<0.001) and evening periods (p<0.05) among boys and during the lunch (p<0.01) and late afternoon (p<0.05) periods among girls.

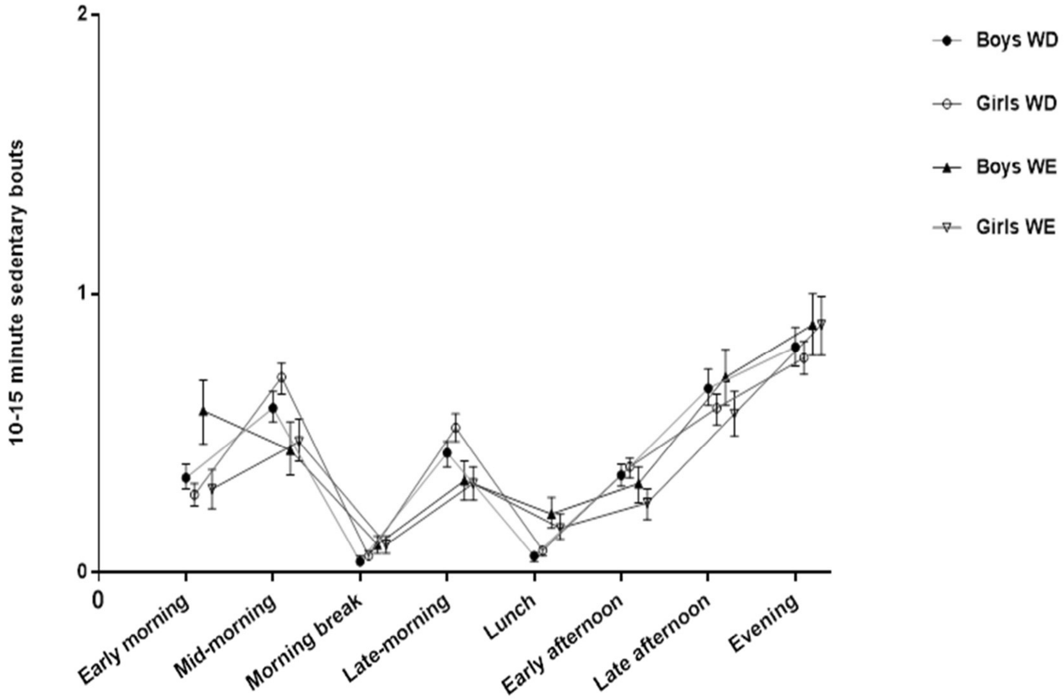

Figure 5.12 Frequency of 10-15 minute sedentary bouts (mean, 95% CI) during weekday and weekend day periods in boys and girls

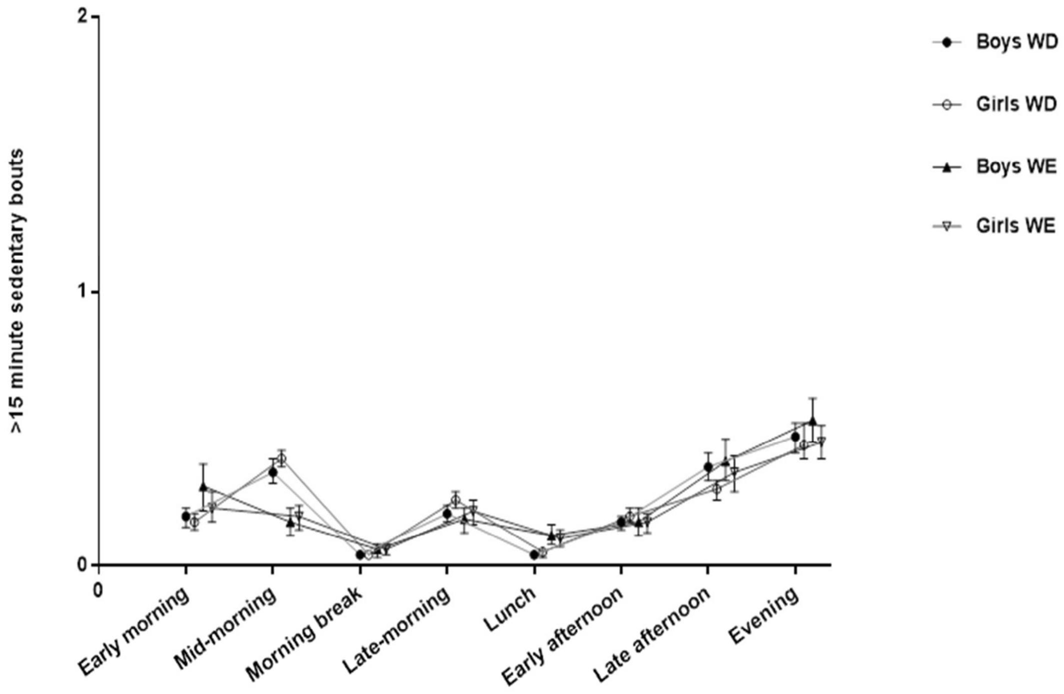

Figure 5.13 Frequency of sedentary bouts longer than 15 minutes (mean, 95% CI) during weekday and weekend day periods in boys and girls

5.5 Discussion

This chapter examined the prevalence and patterns of objectively measured sedentary time in a sample of 7-12 year old Australian children. The main findings were that, approximately 60% of children's total time (as a percentage of accelerometer wear time) was spent sedentary. However, when comparing weekday and weekend day periods there was a distinctly different pattern of accumulation with clear peaks in the percentage of sedentary time on weekdays during class time periods and after school compared to a consistent level of sedentary time during all periods across weekend days. The frequency of bout lengths was highest for 2-5 minute and 5-10 minute bouts and this frequency was highest during periods that comprised a high percentage of sedentary time.

In the current study, children spent 5.5 hours (close to 60%) of their waking time sedentary on weekdays and 6 hours (65%) on weekend days. This is similar to the average sedentary time (≤100 cpm) as measured in NHANES 2003-2004 (Matthews et al. 2008), the UK SPEEDY study (Steele et al. 2010) and the European Youth Heart Study (EYHS) (Nilsson, Anderssen & Andersen 2009), which ranged from 5.0 hours to 7.8 hours per day. However, it contrasts a study of 8-11 year old children in France (Guinhouya et al. 2007), which reported higher levels of sedentary time in boys (11.7 hours) and girls (12.1 hours). However, that study used a cut-point of 1100 cpm to define sedentary time, which has only been validated in 3-4 year olds (Reilly et al. 2003) and it is therefore likely that sedentary time was inflated in their cohort. Importantly, the findings from the current study support widespread concern that children spend high amounts of time sedentary on weekdays and weekend days.

Among girls a greater proportion of time was spent sedentary on weekdays compared to weekend days. An additional 3% of a weekday was spent being sedentary compared to weekend days. Furthermore, girls spent significantly more time sedentary during all of the weekday periods encompassed within school hours compared to boys. Similarly, a study of 10-14 year old children (n=135) in the UK (Bailey et al. 2012) found girls spent significantly more time sedentary during all of the school day periods, yet outside school hours sedentary time patterns were similar to boys. While other studies have also reported differences in sedentary time between boys and girls across periods of the weekday (Guinhouya et al. 2007; Steele et al. 2010), the hour-by-hour assessment of temporal patterns in those studies fails to distinguish between key periods of the day in which intervention may have greatest effectiveness. While the nature of the structured class time sedentary learning environment may be inherently sedentary, the results of the current study suggest that the implications may be greater for girls compared to boys. Furthermore, the recess and lunch break are an opportune time engage in physical activity, yet girls in the current sample spent approximately 40% of that time sedentary. Targeting even small reductions in sedentary time during class periods and break times (recess and lunch) may be an important approach in reducing girl’s overall weekday sedentary time.

Boys had approximately eight less sedentary breaks overall compared to girls on a total weekday and twenty fewer breaks on a weekend day as well as during several periods of the day. Interestingly the periods that comprised of a lower frequency of breaks among boys in the current study also represent periods of greater discretionary time (e.g. morning break and lunch) and boys spent less time sedentary compared to girls during these time periods. Therefore, it is plausible that the lower frequency of breaks is due to the lower percentage of time spent sedentary. An exception, however, is the period of time after school until 6pm which comprised a high proportion of sedentary time and a low level of frequency in sedentary breaks among boys. As found in Chapter 4, children spent approximately two hours in total screen time on a weekday and it is likely that the high percentage of sedentary time and low frequency of breaks in sedentary time during the afternoon period is when high levels of engagement in specific SBBs occur.

Despite an overall similar and high proportion of time spent sedentary on weekdays and weekend days (~ 60%), boys had approximately 25 less breaks and girls had approximately 35 less breaks on a weekday in comparison to a weekend day. Similarly, a recent study of patterns of sedentary behaviour in 10-12 year old children from New Zealand (n=66) (Abbott, Straker & Mathiassen 2014) reported fewer sedentary breaks among boys and girls on weekdays during school time as compared to the equivalent time period on the weekend. As school time represents a large proportion of the waking day, the school environment offers an important opportunity in which to intervene and establish healthy behaviours early in life. In addition to the potential to reduce overall sedentary time through school based interventions, this may be a key time to encourage breaking up sedentary time.

In the current study, children engaged in more 2-5 and 5-10 minute bouts in comparison to longer bouts on weekdays and weekend days. Similarly, a recent study of eleven year old children in Canada (Carson, Stone & Faulkner 2014), found 1-4 minute and 5-9 minute sedentary bouts contributed the greatest percentage of monitor wear time and this was high on weekdays and weekend days. It is likely that when sedentary time is higher, it is the frequency of 2-5 and 5-10 minute bouts that contribute to the sedentary time. For example, among girls there was a higher frequency of 2-5 and 5-10 minute bouts on weekdays compared to weekend days and during several periods of the weekday when sedentary time was also high. Few studies have examined lengths of sedentary bouts in children. In order to inform future sedentary behaviour recommendations and strategies, further research is needed to determine the length of a bout which is biologically meaningful; that is the threshold at which it is beneficial to health to break up prolonged sedentary time in children.

Strengths and limitations

A key strength of the current study is the use of an objective measure of sedentary time, which provides time stamped information about children's sedentary patterns across the day. The customised Excel Macro enabled discrete time periods of the weekday and weekend day as well as specific bout lengths and breaks in sedentary time to be examined. To the candidate's knowledge this study provides some of the first evidence of differences between boys' and girls' patterns of accumulation of sedentary time. However, an important consideration is that while the time of day periods on a weekend were matched to that of weekday to enable direct comparison, it is unlikely that children's behaviour on a weekend day mirrors that of a structured school day (section 3.7.1). In addition, an important consideration in the use of accelerometers is the reliance on a cut-point to define sedentary time as this can considerably influence the results (Cain et al. 2013). While the current study used a widely accepted and validated cut-point of ≤100 cpm, this cut-point determines non-movement but cannot distinguish between sitting and standing time.

Conclusion

The results of the current study indicate periods of the school day and weekday and weekend day may be important for health promotion targets to reduce overall sedentary time. The distinctly higher levels of sedentary time during class time highlights a key need to reduce sedentary time during this period. While reducing overall sedentary time during class periods may be challenging, breaking up this sedentary time at certain increments may be more achievable. However, further research is needed to determine the relevance of uninterrupted sedentary time to children's health and therefore guide health promotion intervention and inform future recommendations. The high levels of engagement in sedentary time on weekdays after school and across all periods of the weekend day indicate that school based strategies alone may not be sufficient to reduce children's sedentary time. However, given the high frequency of shorter bouts of sedentary time, an encouraging implication is the potential to reduce overall total sedentary time by replacing short bouts of sedentary time with light physical activity, for example, which may be more appealing and achievable to children.

As previously discussed accelerometer measured sedentary time relies on a cut-point to differentiate sedentary time and it is not possible to determine if the individual is sitting or standing with little movement. The *activ*PAL^{TM} inclinometer can detect time spent sitting and therefore issues associated with the reliance on cut-points as identified with hip-mounted accelerometers may be overcome.

Chapter 6
Prevalence and patterns of objectively measured sitting time among 7-10 year olds

6.1 Introduction

The previous chapter described the prevalence and patterns of sedentary time among a cohort of 7-12 year old Australian children. As discussed in the literature review (Chapter 2), however, the reliance on arbitrary cut-points to define sedentary time can influence the results obtained as the accelerometer only measures a lack of movement and light intensity activities, such as standing with little movement, may be misclassified as sedentary time. The measurement of bouts and breaks with accelerometers may also be problematic because an increase in counts above a set threshold, rather than a change in posture, determines the end of a bout or a break. Importantly, evidence from adult studies suggests the measurement of breaks in sedentary time with accelerometers may be less accurate than devices specifically designed to measure posture (Lyden et al. 2012).

The importance of differentiating between postures is highlighted by the work of Hamilton and colleagues (Hamilton, Hamilton & Zderic 2007; Hamilton. et al. 2008) which suggests standing, even with only a low level of energy expenditure, is beneficial to health. Furthermore, as discussed in Chapter 2, sedentary behaviour was defined as 'any waking behaviour characterised by a low level of energy expenditure (≤1.5 METs) while in a sitting or reclining position (SBRN 2012). With the increase in awareness of the importance of understanding children's sedentary patterns (Saunders, Chaput & Tremblay 2014), there is a need to use devices which permit the objective measurement of sitting time (Bassett, Freedson & Kozey 2010). The *activ*PAL^{TM} directly measures sitting through the inclination of the thigh without a reliance on self-report or an accelerometer count threshold (Kozey-Keadle et al. 2011). It has been identified as a valid measure of sitting/lying and standing postures in adults (Grant et al. 2006; Kozey-Keadle et al. 2011), adolescents (Dowd, Harrington & Donnelly 2012), primary school aged children (Ridgers et al. 2012) and pre-school children (Davies et al. 2012; Janssen et al. 2013) and has been validated for assessing breaks in sitting time in adults (Grant et al. 2006; Lyden et al. 2012).

To the candidate's knowledge no Australian data have been published that have examined primary school-aged children's patterns of sitting time as measured with the *activ*PAL^{TM}. An important gap in the literature is evidence regarding how much time children spend sitting and how that time is accumulated (i.e. bouts and breaks) during discrete periods of the weekday and weekend day in boys and girls. In order to effectively intervene it is necessary to understand where and how children's sitting time is accumulated during and outside of school hours. The identification of 'usual' periods in which fewer breaks and longer unbroken bouts of sitting time are occurring may have particular relevance to health promotion. This type of information is needed to maximise the effectiveness of strategies and interventions that aim to reduce the time children spend sitting.

6.2 Aims

The aims of this chapter are to:

1. Examine the objectively measured patterns of sitting time within waking periods on weekdays and weekend days; and

2. Determine the frequency of breaks in and bouts of sitting time within waking periods on weekdays and weekend days among 7-10 year old Australian boys and girls.

6.3 Methods

6.3.1 Procedures

The current study comprised a subsample of children from the Transform-Us! study who wore an *activ*PAL^{TM} inclinometer (n=205) for eight days at baseline data collection. The data collection procedures are described in detail in Chapter 3 (see section 3.7.2) and summarised below.

activPAL^{TM}

Children were fitted with the *activ*PAL^{TM} inclinometer on the anterior aspect of the mid-thigh with an adjustable elasticised belt by trained research staff. Participants were asked to wear the *activ*PAL^{TM} during all waking hours and to remove it during water-based activities (e.g. bathing and swimming), as well as contact sports if needed.

Demographics

Parents completed a questionnaire which obtained information on family demographics, including the parent's age, highest level of education, country of birth, employment and marital status.

6.3.2 Data management

The management of inclinometer data is described in detail in section 3.8.1 and summarised below.

Inclinometer data reduction

Briefly, inclinometer data were downloaded into 15-second epochs using PAL Technologies Professional Version 6.1.2. Non-wear time was defined as 20 minutes or more of consecutive zeroes (Cain et al. 2013) as measured by the accelerometer function of the *activ*PAL™. Three valid weekdays (3 x ≥480 mins) and one weekend day (1 x ≥420 mins) was required to be included in whole day analyses, and three valid weekday or one valid weekend day period (50% wear time) to be included in temporal patterns analysis (Hnatiuk et al. 2012; Ridgers et al. 2011).

Sitting time variables

The generated 15-second files were processed with a customised Excel Macro to generate time spent sitting, sit-to-stand transitions and bouts of sitting time within a whole day and specific periods of the day. As described in section 3.8.2, bouts that lasted 2-5, 5-10, 10-15 and ≥15 minutes were examined. The first complete 15-second epoch in which sitting was the identified posture, defined the beginning of a sitting bout and the bout ended when the child transitioned to an upright posture. A sit-to-stand transition was defined as the transition from sitting/lying to standing or stepping.

Periods of the day

As described in section 3.8.1 and Table 3.3, discrete periods of the day were generated on the basis of school bell times.

6.3.3 Data analyses

Analyses were undertaken with Stata/SE version 12 (StataCorp 2011). Descriptive statistics were used to compare the distribution of parent characteristics (percent) and child characteristics (mean, standard deviation) between boys and girls. The distribution of each of the outcome variables were assessed for normality. Differences between boys and girls in the percentage of sitting time, sit-to-stand transitions and bouts of sitting time within a whole day and periods of the weekday and weekend day were examined with independent t-tests. Paired t-tests were undertaken to determine weekday and weekend day differences in the percentage of time spent sitting, the frequency of sit-to-stand transitions and bouts of sitting time within a whole day and periods of the day for boys and girls.

6.4 Results

6.4.1 Characteristics of the sample

Table 6.9 describes the demographic characteristics of the parent/carer and children. The parent questionnaire was predominantly completed by the mother or female carer (boys 74%; girls 81%) and they were typically aged between 20 and 39 years (boys 45%; girls 42%). The majority of boys (53%) and girls (62%) parents were born in Australia. Just over 40 percent of boys' parents and 50 percent of girls' parents reported having a university or tertiary qualification. Approximately 80% of parents were full-time employed, part-time employed or undertook home duties full-time. A higher percentage of the final sample were girls (59%) and the age was similar for boys and girls (8.2 years [SD=0.5] and 8.1 years [SD=0.4], respectively). The average number of valid days was similar in all children with boys having 4.1 (SD=0.8) valid weekdays and girls having 4.2 (SD=0.8) valid weekdays. On weekend days, boys had an average of 1.6 (SD=0.5) valid days and girls had an average of 1.7 (SD=0.5) valid days.

Table 6.9 Family demographic and participant characteristics among boys and girls

	Boys (n=70)		Girls (n=101)	
Characteristic	**Frq (n)**	**%**	**Frq (n)**	**%**
Parent characteristics				
Relationship to child				
Mother/female carer	52	74.3	82	81.2
Father/male carer	11	15.7	7	9.9
Age				
20-39 years	32	45.7	43	42.6
40-49 years	27	38.6	45	44.6
50 + years	3	4.3	1	1.0
Marital status				
Married/defacto	52	74.3	83	82.2
Separated/divorced	7	10.0	4	4.0
Other[a]	3	4.3	2	2.0
Country of birth				
Australia	37	52.9	63	62.4
Other[b]	26	37.1	26	25.7
Level of education				
University or tertiary	29	41.4	54	53.5
Other[c]	33	47.1	35	34.7
Employment				
Full-time or part-time employed	43	61.4	52	51.5
Home duties full-time	14	20.0	31	30.7
Other[d]	5	7.1	6	5.9
Child characteristics				
Sex	70	40.9	101	59.1
Age (mean, SD)	8.2 (0.5)		8.1 (0.4)	
No. valid weekdays (mean, SD)	4.1 (0.8)		4.2 (0.8)	
No. valid weekend days (mean, SD)	1.6 (0.5)		1.7 (0.5)	

Not all frequencies equal to 70 (boys) and 101 (girls) due to missing parent survey data. Values represent mean (standard deviation, SD), determined by independent t-tests or percentage (%) determined by Pearson chi-square.

6.4.2 Whole day percentage of sitting time, sit-to-stand transitions and bouts of sitting time

Table 6.10 describes the percentage of time boys and girls spent sitting, the frequency of sit-to-stand transitions and bouts of sitting time on a total weekday and weekend day.

Daily patterns of sitting time – boys compared to girls

There were no significant differences between boys and girls in the percentage of time spent sitting, hours of sitting time, breaks in sitting time, 2-5 minute bouts of sitting time or ≥15 minutes on a total weekday or weekend day. Girls had a higher frequency of 10-15 minute sitting bouts compared to boys on a total weekday ($p<0.05$) and 5-10 minute sitting bouts on a weekend day ($p<0.05$).

Daily patterns of sitting time – weekday compared to weekend day

Among boys and girls there were no significant differences in the average whole day percentage of sitting time on weekdays compared to weekend days; however, hours of sitting time was higher on weekdays compared to weekend days among boys ($p<0.001$) and girls ($p<0.01$). The average frequency of 2-5 and 5-10 minute sitting bouts was significantly higher on weekdays compared to weekend days among boys ($p<0.01$) and girls ($p<0.001$). For boys, the average frequency of 10-15 minute sitting bouts was significantly higher on weekdays compared to weekend days. There was no difference between weekdays and weekend days in the average daily frequency of sitting bouts ≥15 minutes among boys or girls.

Table 6.10 Sitting time (hours), percentage of sitting time and frequency of breaks and bouts in sitting time during a whole weekday and weekend day in boys and girls

	Weekday (n=139)				Weekend day (n=132)			
	All children	**Boys**	**Girls**	***p* for sex**	**All children**	**Boys**	**Girls**	***p* for sex**
Percentage	59.6 (11.0)	60.1 (14.0)	59.0 (7.9)	0.56	58.5 (14.7)	58.9 (17.8)	58.0 (11.6)	0.70
Hours	6.7 (1.4)	6.8 (1.7)	6.5 (1.0)	0.24	6.4 (1.8)	6.1 (2.1)†	6.6 (1.5)**	0.85
sit-to-stand transitions	87.6 (22.2)	85.2 (25.4)	89.9 (19.0)	0.21	82.2 (27.5)	78.2 (29.5)	86.2 (25.5)	0.09
Bouts (Frq)								
2-5 mins	17.6 (4.9)	17.4 (5.7)	17.9 (4.1)	0.55	15.1 (5.9)	14.7 (6.5)**	15.5 (5.2) †	0.43
5-10 mins	11.3 (3.1)	10.8 (3.3)	11.8 (2.8)	0.06	9.8 (3.8)	9.1 (4.2)**	10.5 (3.4)**	0.03
10-15 mins	5.2 (1.7)	4.8 (1.8)	5.5 (1.5)	0.01	4.6 (2.5)	4.2 (2.1)*	4.9 (2.8)	0.08
≥15 mins	6.0 (2.0)	6.1 (2.2)	5.9 (1.7)	0.60	6.2 (2.9)	6.0 (3.0)	6.3 (2.8)	0.63

Values represent mean (SD) determined by independent-samples t-test

Differences within sex between weekdays and weekend days determined by paired-samples t-tests and significance indicated by: * $p<0.05$; ** $p<0.01$; † $p<0.001$

6.4.3 Temporal patterns of sitting time, sit-to-stand transitions and bouts of sitting time across periods of the weekday and weekend day

The results for the analysis of percentage of sitting time, sit-to-stand transitions and bouts of sitting time across periods of the weekday and weekend day in boys and girls are shown in Figures 6.14-6.19 with values presented as mean, 95% confidence intervals (CI). The corresponding tables of numerical data are presented for information in Appendix E.2.

Percentage of sitting time – boys compared to girls

As shown in Figure 6.14, there were no significant differences between boys and girls in the percentage of time spent sitting during weekday or weekend day periods.

Percentage of sitting time – weekday compared to weekend day

During the mid-morning, late morning and early afternoon periods (Figure 6.14), boys and girls spent a significantly higher percentage of time sitting on weekdays compared to weekend days (p<0.001). On weekend days, boys and girls spent a significantly higher percentage of time sitting during the periods of the day that corresponded with morning break and lunch period on weekdays (p<0.001). There were no differences for boys or girls in the percentage of time spent sitting during the late afternoon and evening periods on weekdays compared to weekend days.

Frequency of sit-to-stand transitions – boys compared to girls

As shown in Figure 6.15, boys had a lower frequency of sit-to-stand transitions compared to girls during the morning break period ($p<0.05$), the lunch period ($p<0.01$) and the late afternoon period ($p<0.05$) on weekdays. On weekend days, boys had a lower frequency of sit-to-stand transitions during the mid-morning period compared to girls ($p<0.001$).

Frequency of sit-to-stand transitions – weekday compared to weekend day

Boys had a lower frequency of sit-to-stand transitions during the early morning ($p<0.01$) and mid-morning period ($p<0.01$) on weekend days compared to weekdays (Figure 6.15). Among girls the frequency of sit-to-stand transitions was significantly lower on weekdays during the mid-morning period compared to weekend days ($p<0.05$). During the lunch period on weekend days the frequency of sit-to-stand transitions was lower compared to weekdays ($p<0.01$).

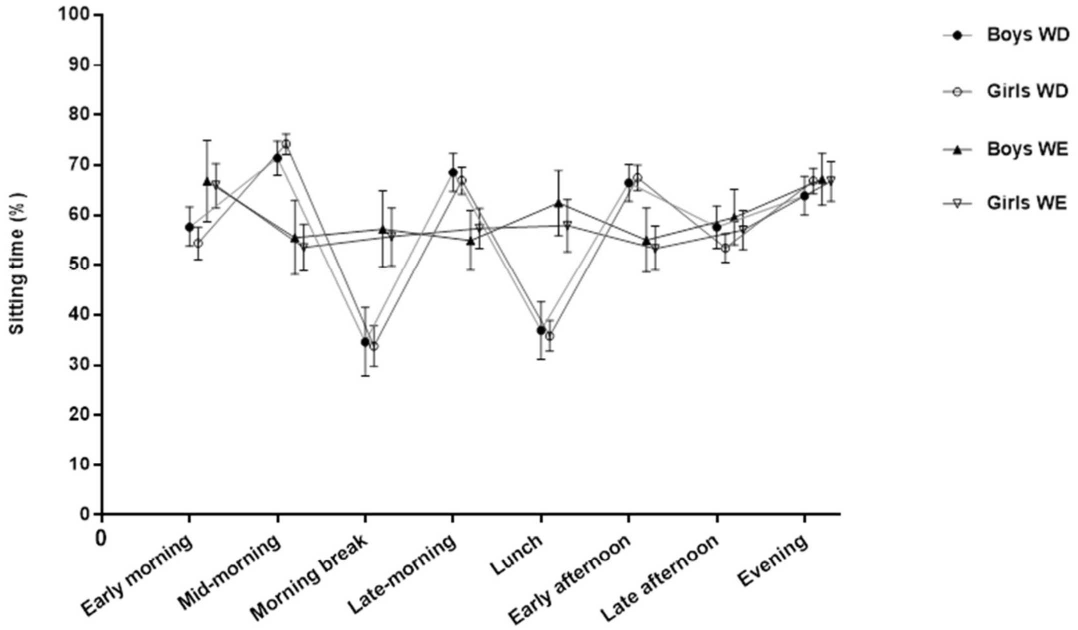

Figure 6.14 Average percentage of time spent sitting (mean, 95% CI) during weekday and weekend day periods among boys and girls

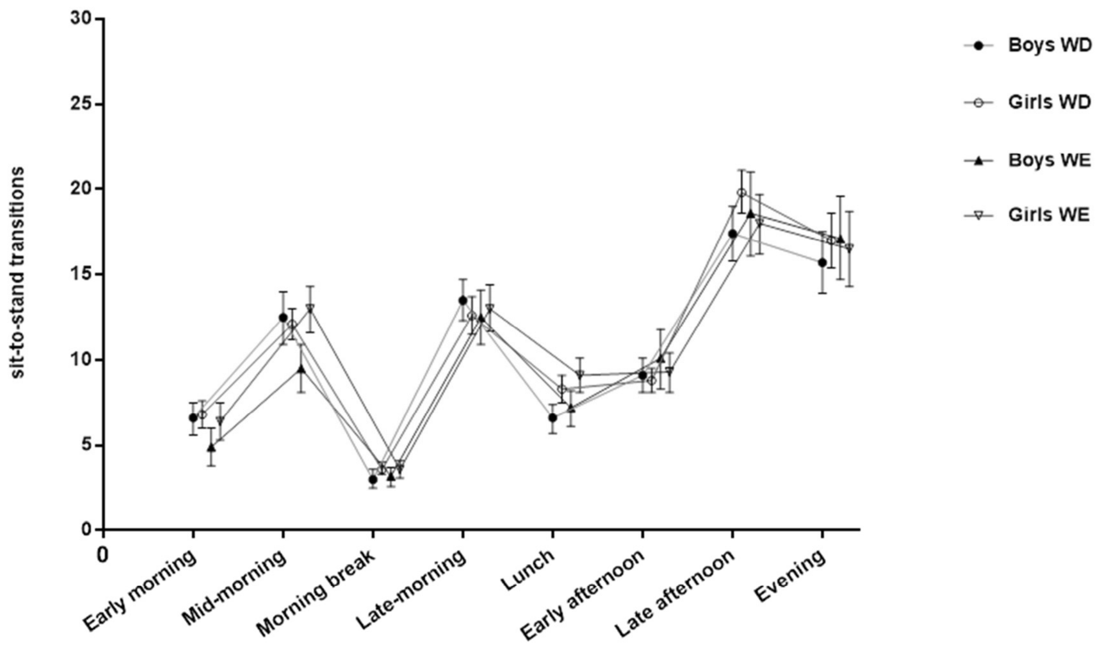

Figure 6.15 Average frequency of breaks in sitting time (mean, 95% CI) during weekday and weekend day periods in boys and girls

Frequency of 2-5 minute sitting bouts – boys compared to girls

Figure 6.16 shows the frequency of 2-5 minute sitting bouts in boys and girls on weekdays and weekend days. The average frequency of 2-5 minute sitting bouts was significantly higher among girls compared to boys during the lunch period on a weekday ($p<0.01$). On a weekend day the average frequency of 2-5 minute sitting bouts was significantly higher among girls compared to boys in the early morning period ($p<0.05$). No other significant differences between boys and girls were observed.

Frequency of 2-5 minute sitting bouts – weekday compared to weekend day

During periods of the weekday boys and girls (Figure 6.16) had a significantly higher frequency of 2-5 minute sitting bouts during the mid-morning period compared to the weekend day time period ($p<0.001$ and $p<0.05$, respectively). On weekdays the frequency of 2-5 minute sitting bouts was also higher for boys during the early morning ($p<0.01$), and girls during the late morning ($p<0.01$) and early afternoon ($p<0.001$) periods compared to weekend days. On weekend days the frequency of 2-5 minute sitting bouts was higher among boys during the morning break ($p<0.05$) and lunch period ($p<0.01$) compared to the weekday day period.

Frequency of 5-10 minute sitting bouts – boys compared to girls

Figure 6.17 shows the frequency of 5-10 minute sitting bouts in boys and girls on weekdays and weekend days. There was no difference in the frequency of 5-10 minute sedentary bouts between boys and girls during periods of the weekday.

On weekend days the average frequency of 5-10 minute sitting bouts was significantly higher among girls than boys during the mid-morning period ($p=0.03$).

Frequency of 5-10 minute sitting bouts – weekday compared to weekend day

On weekday periods, boys and girls had a higher frequency of 5-10 minute sitting bouts during the mid-morning ($p<0.001$ and $p<0.01$ respectively) and late morning ($p<0.05$ and $p<0.01$, respectively) periods on in comparison to weekend days (Figure 6.17). Boys also had a higher average frequency of 5-10 minute sitting bouts on a weekday during the early afternoon period ($p<0.01$) and among girls during the late afternoon period ($p<0.01$) compared with weekend days. In contrast, on weekend days there was a higher frequency of 5-10 minute sitting bouts among boys and girls during the morning break ($p<0.001$ and $p<0.05$ respectively) and lunch period ($p<0.001$ and $p<0.05$ respectively) compared to weekdays.

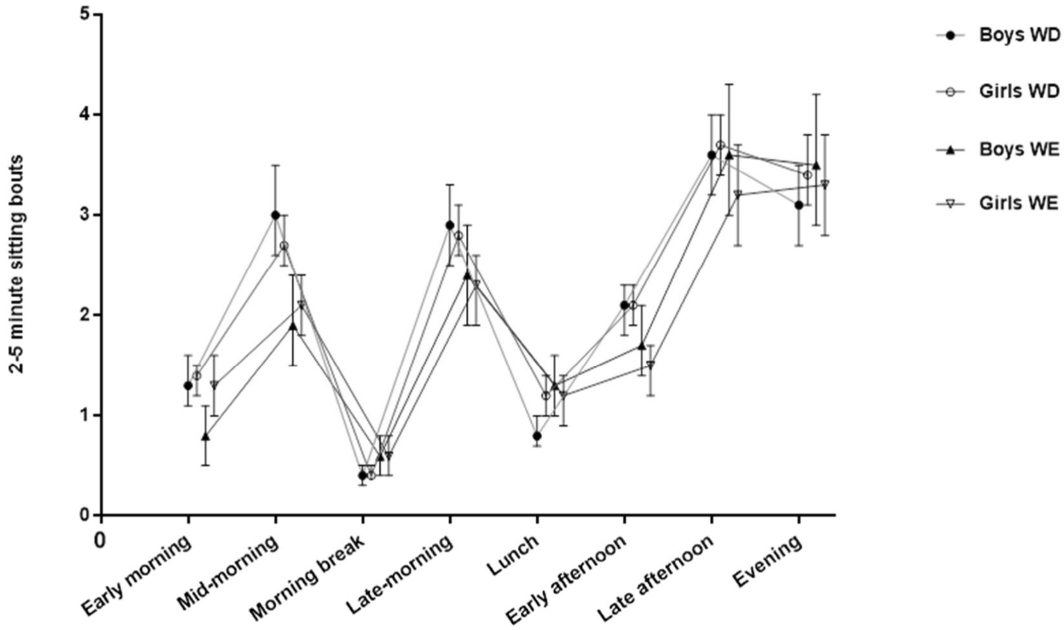

Figure 6.16 Average frequency of 2-5 minute sitting bouts (mean, 95% CI) during weekday and weekend day periods in boys and girls

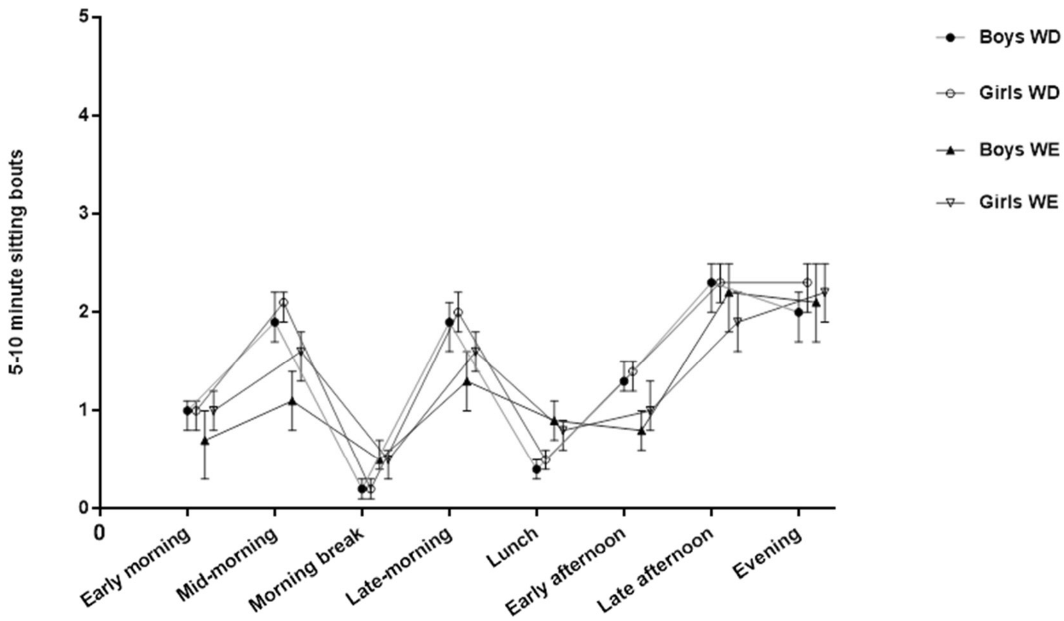

Figure 6.17 Average frequency of 5-10 minute sitting bouts (mean, 95% CI) during weekday and weekend day periods in boys and girls

Frequency of 10-15 minute sitting bouts – boys compared to girls

Figure 6.18 shows the frequency of 10-15 minute sitting bouts in boys and girls on weekdays and weekend days. Girls had a higher frequency of 10-15 minute sitting bouts during the mid-morning period on weekdays compared to boys ($p<0.05$). On weekend days girls had a higher frequency of 10-15 minute sitting bouts during the early afternoon period compared to boys ($p<0.05$).

Frequency of 10-15 minute sitting bouts – weekday compared to weekend day

Boys had a higher average frequency of 10-15 minute sitting bouts on weekdays during the early afternoon period ($p<0.05$) compared to weekend days (Figure 6.18). During weekend periods the average frequency of 10-15 minute bouts was higher for boys during the morning break ($p<0.05$) and lunch ($p<0.001$) periods. Girls had a higher average frequency of 10-15 minute sitting bouts during the late morning period ($p<0.05$) compared to weekend days. On weekend days girls had a higher average frequency of 10-15 minute sitting bouts days during morning break ($p<0.01$) and lunch ($p<0.001$) compared to the corresponding weekday periods.

Frequency of ≥15 minute sitting bouts – boys compared to girls

Figure 6.19 shows the frequency of ≥15 minute sitting bouts in boys and girls on weekdays and weekend days. There were no significant differences between boys and girls in the average frequency of ≥15 minute bouts in periods of a weekday. On weekend days boys had a higher frequency of ≥15 minute bouts in the early morning period compared to girls ($p<0.05$).

Frequency of ≥15 minute sitting bouts – weekday compared to weekend day

During periods of the weekday boys had a higher frequency of ≥15 minute bouts on during the mid-morning period ($p<0.05$) compared to weekend days (Figure 6.19). The average frequency of ≥15 minute bouts was higher in boys during the morning break ($p<0.05$), lunch ($p<0.001$) and the evening ($p<0.05$) periods. Girls had a higher average frequency of ≥15 minute bouts on weekdays during the early afternoon period ($p<0.05$). On weekend days girls had a higher average frequency of ≥15 minute bouts during the mid-morning ($p<0.05$), morning break ($p<0.001$), lunch ($p<0.05$) and the evening ($p<0.05$) periods compared to the corresponding weekday periods.

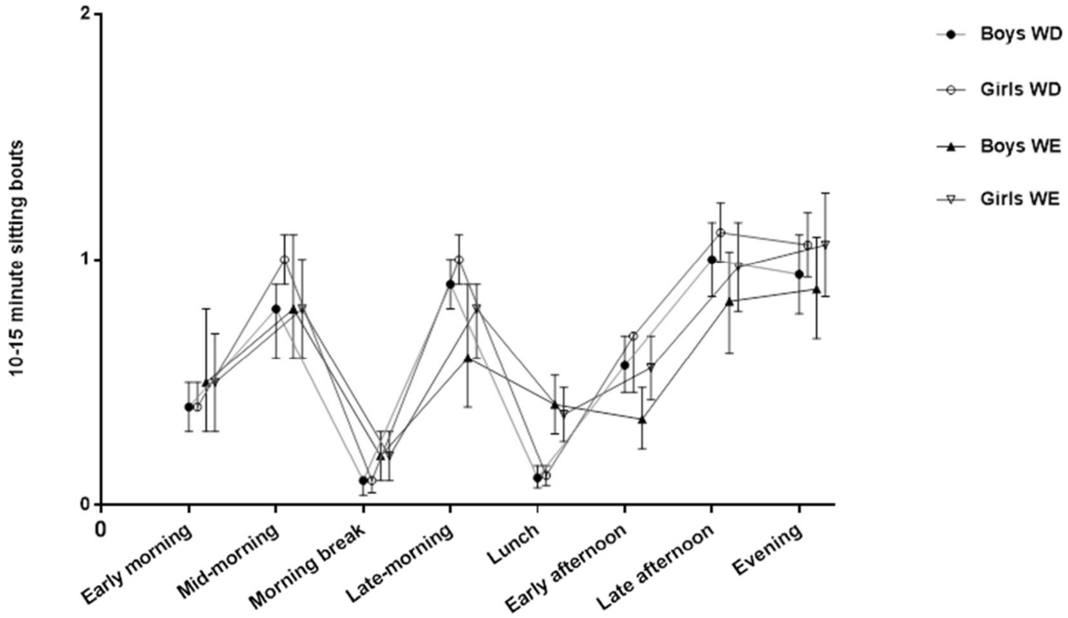

Figure 6.18 Average frequency of 10-15 minute sitting bouts (mean, 95% CI) during weekday and weekend day periods in boys and girls

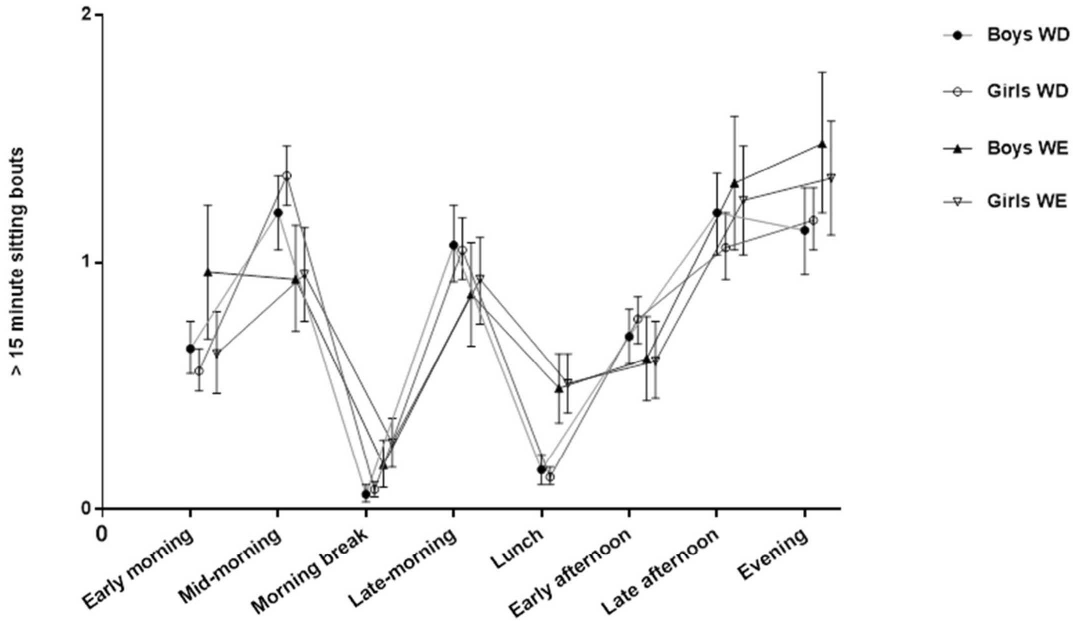

Figure 6.19 Average frequency of sitting bouts ≥15 minutes (mean, 95% CI) during weekday and weekend day periods in boys and girls

6.5 Discussion

This chapter described the prevalence and patterns of objectively measured sitting time in a sample of 7-10 year old Australian children. Approximately 60% of children's total time (as a percentage of inclinometer wear time) was spent sitting on weekdays and weekend days. Notably, the pattern of accumulation of sitting time across periods of the day was similar for boys and girls. However, when comparing weekday and weekend days there was a distinctly different pattern, with clear peaks in sitting time on weekdays during class time and after school compared to a consistent level of sitting time during all periods across the weekend day. The frequency of weekday sit-to-stand transitions followed a similar pattern to the percentage of sitting time within periods of the weekday such that high levels of sitting time equated to a high frequency of sit-to-stand transitions. The frequency of bout lengths was highest for 2-5 minute and 5-10 minute bouts on weekdays and weekend days. On weekdays this frequency was higher during periods that comprised a high percentage of sitting time. With the exception of 5-10 minute bouts, the pattern of sit-to-stand transitions and bouts of sitting time on a weekend day followed a similar pattern to the percentage of sitting time within periods of the weekday.

To the best of the candidate's knowledge the prevalence of sitting time has not been examined in primary school aged children. The percentage of time spent sitting among children in the current study (approximately 60%) was lower than that reported in a recent study of adolescent girls (age 15-18 years) who spent 78% of the total day sitting (Harrington et al. 2011). However, the difference between studies is likely to reflect the younger age group of the current study particularly as adolescents are consistently reported to spend higher levels of time sedentary compared to younger age groups (Jago et al. 2005; Ruiz et al. 2011; Treuth et al. 2005).

Although the total daily percentage of sitting time was similar on a weekday and weekend day, there was a distinct difference in patterns of sitting time across periods of the day. Clear peaks in sitting time were observed during weekday periods compared to a consistent high level of sitting time across all periods of the weekend day. Not surprisingly, during the school day, there was a similarly high level of sitting time during class periods (~ 60%) and significantly lower levels of sitting time during the recess and lunch breaks (~ 40%). Similarly, an Australian study of 56 children aged 8-12 years reported a much greater amount of time spent sitting during class time compared to break time (Ridgers et al. 2012), which may reflect the boundaries of structured class time and also the importance of recess and lunch for physical activity. The findings of the current study highlight that on the one hand the structure of the school day can promote extended sitting during lessons, however it can also result in lower levels of sitting during recess and lunchtime breaks.

Similarly to the high percentage of sitting time in class there was a high percentage of sitting time in the afternoon and evening periods on a weekday. Considering children were found to spend on average two hours in screen time during leisure time on a weekday (Chapter 4) it is not surprising that sitting time was high during this time. In addition, it is concerning that on weekend days children spent more than half of their time sitting across periods of the day with little variation other than an even greater percentage in sitting time of nearly 70%

during the early morning and evening. Average daily screen time on a weekend day was approximately 4.5 hours and it is possible that the high and consistent percentage of sitting time reflects ongoing engagement in SBBs during this time. With the exception of recess and lunch breaks, during the school day, the results suggest that when children have discretionary leisure time, be it on a weekday or weekend day, sitting based pursuits comprise a high percentage of their time. While class time may be an important opportunity to reduce sitting time, the consistently high level of sitting time across weekend days suggests strategies to reduce sitting time will also need to target children's outside school hours leisure time. As the *activ*PAL™ does not provide information on what children are doing during their leisure time, further research, with log books or time-use-diaries, could provide such information.

The frequency of breaks in sitting time was higher during weekday periods in which the percentage of sitting time was also high. However, on weekend days, which showed a consistently high level of sitting time percentage across all periods, there were distinct drops in the frequency of breaks in sitting time. Therefore, during weekend periods when children are assumed to have more discretionary time, periods of high sitting time may not be as interrupted compared to the equivalent weekday time period. It is plausible those periods in which there was a high percentage of sitting time and a low frequency of breaks reflect screen time engagement. However, a similar trend was not observed on weekdays or weekend days during the evening period when the percentage of sitting time was highest and screen time is also likely to be high.

Children spent the majority of their sitting time in short bouts of 2-5 and 5-10 minutes. Even during class times, the frequency of these shorter bouts of sitting was more common than the longer bouts. However, during these periods there was also a higher frequency of bouts lasting longer than 15 minutes which is likely to reflect uninterrupted sitting in class. In a study of adolescent girls (Harrington et al. 2011) there was a higher frequency of longer sitting bouts (21-40 minutes) on weekdays compare to weekend days and the authors suggested the school day appeared to promote continuous unbroken bouts of sitting. However, in the current study the frequency of bouts longer than 15 minutes was also higher during several periods of a weekend day which may reflect time spent in specific SBBs during discretionary leisure time. There was much greater variation in sedentary bouts between boys and girls measured with the ActiGraph accelerometer (Chapter 5) although as previously discussed this may be due to the inclusion of standing with little movement.

Strengths and limitations

The use of devices that measure posture have been encouraged to determine the amount of time children spend sitting as they overcome issues associated with a reliance on accelerometer determined cut-points and self-reported time spent sedentary. The current study provides some of the first information on 7-10 year olds' prevalence and patterns of objectively measured sitting time. It provides an insight into the way in which sitting time is accumulated across periods of the school day and weekend day for boys and girls. However, the results should be interpreted with caution because the sample size is limited and the data are descriptive and not generalisable to population groups outside of Australian children aged between 7 and 10 years.

Conclusion

While school provides lots of opportunity for sitting throughout the day, the recess and lunch periods are an important time period in which to promote physical activity. However, the peaks in sitting time in the afternoon and evening periods on a weekday and the ‘flat line’ that was characteristic of the sitting pattern on weekends highlights the tendency for children’s leisure time to be spent engaged in high levels of sitting time. While on a weekday day, periods in which there was a high percentage of sitting time corresponded with a higher frequency of breaks and shorter bouts of sitting time the same pattern was not evident across all weekend day periods. In line with the new Australian Physical Activity and Sedentary Behaviour Guidelines to break up sitting time, this finding reinforces the need for health promotion strategies to reduce and break up sitting time not just in the school environment but equally during children’s leisure time. However, there remains major gaps in evidence of associations between these sitting patterns and children’s CVD risk factors, which will be examined in subsequent chapters.

Chapter 7
Associations between screen-based behaviours and objectively measured sedentary and sitting time

7.1 Introduction

Children from the Transform-Us! study spent approximately two hours per weekday and four hours per weekend day in screen time (Chapter 4). However, children have numerous opportunities to be sedentary, including transport and leisure-time pursuits. Self- and proxy-reported screen time, typically TV viewing, is the dominant measure of sedentary time due to ease of administration, low cost (as compared to objective measures) and minimal participant burden (Trost 2007). However, it is not known whether the children who engage in high levels of screen time are the most sedentary overall.

If measures of overall screen time or specific SBBs are positively associated with total sedentary or sitting time, simple behavioural questions may be a useful screening tool for the identification of children at risk of a sedentary lifestyle. Furthermore, if certain sedentary behaviours provide good representation of overall sedentary time, this may alleviate the need to use objective measures of total sedentary or sitting time, which can have prohibitively high costs and greater subject burden. In addition, the identification of specific indicator behaviours may inform behavioural targets for interventions to reduce children's sedentary behaviour. Conversely, if screen time is not a good marker of overall sedentary behaviour levels, studies that have only examined screen time may fail to capture children at risk of a sedentary lifestyle.

Research conducted in adult populations has reported positive associations between TV viewing and subjectively (Sugiyama et al. 2008) and objectively measured (Clark et al. 2011) sedentary time. The study by Sugiyama et al. (2008) reported a positive association between TV viewing and other leisure time sedentary pursuits in women, but not men, suggesting there may be differences between males and females in the association between specific SBBs and overall sedentary time. However, in a study of adolescents there was a null association between TV viewing and other self-reported leisure-time sedentary pursuits (Biddle, Gorely & Marshall 2009). Few studies have examined the association between time spent in specific SBBs and objectively measured sedentary time in young people and the evidence is equivocal. One study reported a positive but weak association between screen time (TV viewing, e-games and computer use) and accelerometer determined sedentary time in 9-10 year olds (Kiltsie et al. 2013). However, in 10-12 year olds from European countries there was insufficient evidence to suggest time spent in TV viewing and computer use reflected overall sedentary time (Verloigne et al. 2013).

As discussed in Chapter 2, emerging evidence suggests that the way in which children accumulate their sedentary time (i.e. breaks and bouts) may be important to health and this is reflected in the new Australia's Physical Activity and Sedentary Behaviour Guidelines (The Department of Health 2014). Due to the passive nature of SBBs, in particular TV viewing, it may be that engagement in certain SBBs reflects fewer breaks in sedentary time and longer bouts of sedentary time. Therefore, an important gap in the literature is evidence of the association between specific SBBs and objectively measured patterns of sedentary time. Furthermore, while accelerometers provide an objective measurement of sedentary time, the reliance on cut-points means certain behaviours may be misclassified as sedentary (e.g. standing with little movement). To the candidate's knowledge there is no published evidence of the association between children's time spent in specific SBBs and patterns of sedentary time as assessed with accelerometers or inclinometers.

7.2 Aim

The aim of this chapter is to examine the cross-sectional associations between time spent in specific SBBs and objectively measured prevalence and patterns (bouts and breaks) of sedentary and sitting time in a sample of Australian boys and girls.

7.3 Methods

7.3.1 Procedures

The current study utilised baseline data from Year 3 children participating in the Transform-Us! study. The measures included family demographics, children's proxy-reported time spent in specific SBBs and objectively measured time spent sedentary and sitting. These measures are described in detail in Chapter 3 and summarised briefly below.

Sedentary time was measured with the ActiGraph GT3X accelerometer (section 3.7.1) and sitting time with the *activ*PAL™ inclinometer (section 3.7.2). Children were instructed to wear the accelerometer and inclinometer for 8 days during waking hours and to remove the devices during water-based activities (e.g.

bathing and swimming). As described in section 3.7.3 and 3.7.4, time spent in specific SBBs (Appendix C.3) and family demographics (Appendix C.4) were obtained by parental-proxy report.

7.3.2 Data management

The management procedures for the questionnaire, accelerometer and inclinometer data (including the extraction of patterns, i.e. breaks in and bouts of sedentary and sitting time) are described in detail in section 3.8 and summarised below.

TV viewing, e-games, computer use and total screen time

The question relating to the different SBBs obtained information on the time spent in TV viewing, electronic games, and computer use (section 3.8.3). The parent was asked to circle “yes” or “no” to indicate if their child usually participated in TV viewing, e-games and computer use and to specify the total amount of time spent in that behaviour from Monday to Friday and on the weekend. The total for Monday to Friday was divided by five to obtain an average weekday amount and for Saturday and Sunday was divided by two to obtain an average weekend day amount. TV viewing, playing e-games and using a computer were treated as separate behaviours and were also combined to create an overall variable for screen time to assess compliance with screen time guidelines (as described in Chapter 4).

Accelerometer data reduction

The management of accelerometer data is described in detail in section 3.8.1. Briefly, accelerometer data were downloaded in 15-second epochs using Actilife Monitoring System, Version 5.1. Non-wear time was defined as 20 minutes or more of consecutive zeroes (Cain et al. 2013) and wear time was calculated by subtracting non-wear time from the total waking day (i.e. 6am-10pm). A valid weekday and weekend day was considered to be 480 minutes or more and 420 minutes or more respectively of wear time. Participants were required to have at least 3 valid weekdays and one valid weekend day.

Sedentary time variables

The raw files were processed with a customised Excel Macro programme to generate sedentary time, breaks in sedentary time and bouts of sedentary time within a weekday and weekend day. Sedentary time was defined as ≤100 cpm (Ridgers et al. 2012; Trost, S. G. et al. 2011). As described in section 3.8.2, bouts that lasted 2-5, 5-10, 10-15 and ≥15 minutes were examined. The first complete 15-second epoch of sedentary time (i.e. ≤25 counts/15s) defined the beginning of a sedentary bout and the last consecutive sedentary epoch defined the end of a sedentary bout. A sedentary break was defined as an interruption in sedentary time in which the accelerometer counts changed from ≤25 counts/15s to >25 counts for the epoch.

Inclinometer data reduction

The management of inclinometer data is described in detail in section 3.8.1. Briefly, inclinometer data were downloaded into 15-second epochs using PAL Technologies Professional Version 6.1.2. The accelerometer protocols (described in Chapter 5) were applied to the management of the *activ*PAL™ data. Non-wear time was defined as 20 minutes or more of consecutive zero's (Cain et al. 2013) as measured by the accelerometer function of the *activ*PAL™ and wear time was calculated by subtracting non-wear time from the total waking day (i.e. 6am-10pm). A valid weekday and weekend day was considered to be 480 minutes or more and 420 minutes or more respectively of wear time. Participants were required to have at least 3 valid weekdays or one valid weekend day to be included in whole day analyses.

Sitting time variables

The raw files were processed with a customised Excel Macro to generate time spent sitting, breaks in sitting time and bouts of sitting time (see section 3.8.2). Bouts that lasted 2-5, 5-10, 10-15 and ≥15 minutes were examined. The first complete 15-second epoch in which sitting was the identified posture, defined the beginning of a sitting bout and the bout ended when the child transitioned to an upright posture. A sitting break was defined as the transition from sitting/lying to standing or stepping.

7.3.3 Data analyses

Analyses were undertaken with Stata (version 12). As data were normally distributed, independent t-tests were used to determine differences in the mean time spent sedentary and the frequency of breaks in and bouts of sedentary time in children who met screen time guidelines and exceeded screen time guidelines. All t-tests were carried out for boys and girls separately and were repeated for inclinometer determined sitting time and the frequency of breaks in and bouts of sitting time. Linear regression analyses were undertaken to examine the association between time spent in specific SBBs and sedentary time and breaks in and bouts of sedentary time on weekdays and weekend days. As data were collected at the school level, clustering by school was adjusted for. Monitor wear time was inversely correlated with sedentary time ($p<0.05$) and was therefore adjusted for in all analyses. All analyses with accelerometer variables were repeated for inclinometer determined sitting time, sit-to-stand transitions and bouts of sitting time.

7.4 Results

7.4.1 Family demographics

The demographic characteristics of children with a valid measure for time spent in TV viewing, e-games and computer use has previously been presented (Chapter 4, Table 4.6). In the current study, 429 children had valid measures for time spent in each of the specific SBBs. Of those children, 405 wore an ActiGraph accelerometer and 290 (71.5%; 43.3% boys) had at least three valid weekdays or one valid weekend day. Among children who wore an *activ*PAL^{TM}

inclinometer (n=205), the valid wear criteria was met by 121 children (60%; 44% boys) who also had a valid measure for each of the specific SBBs.

7.4.2 Screen time compliance and patterns of sedentary time on weekdays and weekend days

There were no significant differences in the percentage of time spent sedentary or breaks in and bouts of sedentary time among children who exceeded screen time guidelines compared to children who met screen time guidelines (Table 7.11).

Table 7.11 Sedentary time (%) and frequency (mean, SD) of breaks in and bouts of sedentary time among children who met screen time guidelines compared to children who exceed screen time guidelines on weekdays and weekend days (n=289)

	Weekday		**Weekend day**	
	< 120 mins/day	**≥ 120 mins/day**	**< 120 mins/day**	**≥ 120 mins/day**
All children (n)	166	123	66	202
Sedentary time (mean %, SD)	55.4 (6.6)	54.8 (7.8)	54.9 (8.8)	56.8 (8.1)
Sedentary breaks	152.4 (27.6)	157.5 (29.9)	286.0 (65.2)	284.6 (67.2)
2-5 min bouts	18.2 (4.2)	18.6 (4.3)	35.3 (7.8)	36.4 (9.0)
5-10 min bouts	5.7 (2.0)	5.6 (2.2)	10.3 (4.0)	11.2 (4.6)
10-15 min bouts	1.5 (0.8)	1.5 (0.8)	2.3 (1.6)	2.7 (1.9)
≥ 15 min bouts	0.8 (0.6)	0.7 (0.6)	1.3 (1.2)	1.4 (1.3)
Boys (n)	70	55	21	90
Sedentary time (mean %, SD)	55.4 (6.5)	53.8 (8.2)	54.2 (8.9)	57.7 (8.2)
Sedentary breaks	145.3 (27.1)	155.1 (27.3)	270.1 (58.3)	277.2 (62.3)
2-5 min bouts	18.0 (4.4)	19.4 (4.9)	33.2 (7.8)	37.6 (9.1)
5-10 min bouts	5.7 (2.0)	5.7 (2.1)	10.1 (4.2)	12.3 (4.8)
10-15 min bouts	1.6 (0.8)	1.5 (0.9)	2.3 (1.6)	2.9 (2.1)
≥15 min bouts	0.8 (0.5)	0.8 (0.7)	1.1 (0.9)	1.5 (0.1)
Girls (n)	96	68	45	112
Sedentary time (mean %, SD)	55.3 (6.7)	53.9 (7.5)	55.2 (8.8)	56.1 (8.0)
Sedentary breaks	157.6 (26.9)	159.5 (31.9)	294.0 (67.7)	290.1 (70.7)
2-5 min bouts	18.3 (4.1)	18.0 (3.8)	36.3 (7.7)	35.4 (8.9)
5-10 min bouts	5.7 (2.1)	5.6 (2.2)	10.3 (3.9)	10.4 (4.2)
10-15 min bouts	1.4 (0.7)	1.4 (0.8)	1.1 (0.9)	1.5 (1.3)
≥15 min bouts	0.8 (0.6)	0.7 (0.5)	1.4 (1.4)	1.3 (1.3)

Values represent mean (standard deviation, SD).

7.4.3 Associations between time spent in specific SBBs and patterns of sedentary time

Weekdays

TV viewing time, computer use and e-games were not associated with the percentage of sedentary time in boys or girls on weekdays or weekend days (Table 7.12).

Weekend days

Time spent playing e-games was positively associated with sedentary time in all children. TV viewing time, computer use and e-games were not associated with the percentage of sedentary time in boys or girls (Table 7.12).

Table 7.12 Unstandardised regression coefficients of average daily time (hours) spent in specific SBBs and average daily sedentary time (mins) among boys and girls on weekdays and weekend days

	All children **β (95% CIs)**	**Boys** (n=125) **β (95% CIs)**	**Girls** (n=164) **β (95% CIs)**
Weekday sedentary time			
TV	-1.86 (-5.59, 1.88)	-2.86 (-9.40, 3.67)	-1.23 (-5.56, 3.09)
E-games	0.79 (-10.29, 1.88)	5.30 (-12.85, 23.46)	-5.81 (-15.94, 3.87)
Computer	-0.85 (-8.73, 7.02)	1.03 (-10.72, 12.79)	-2.45 (-15.24, 10.34)
Total screen	-1.09 (-3.69, 1.50)	-0.89 (-6.30, 4.52)	-1.32 (-4.42, 1.77)
Weekend day sedentary time			
TV	-0.99 (-5.36, 3.38)	-1.84 (-8.27, 4.60)	-0.57 (-7.44, 6.31)
E-games	**7.11 (0.20, 14.02)***	6.07 (-3.72, 15.86)	8.3 (-4.91.21.51)
Computer	5.39 (-2.90, 13.68)	0.94 (-11.65, 13.53)	9.08 (-3.41, 21.57)
Total screen	1.45 (-1.65, 4.55)	0.85 (-4.07, 5.78)	1.73 (-3.6, 7.10)

All values are unstandardised β, 95% confidence intervals (CI) after adjusting for average daily accelerometer wear time (mins) and school cluster.
*p<0.05

There were no significant associations between time spent in specific SBBs and breaks in and bouts of sedentary time among all children or among boys or girls on weekdays (Table 7.13).

Table 7.13 Unstandardised regression coefficients of average weekday time (hours) spent in specific SBBs and frequency of breaks in and bouts of sedentary time

	All children β (95% CIs)	Boys (n=125) β (95% CIs)	Girls (n=164) β (95% CIs)
Sedentary breaks			
TV	0.58 (-1.79, 2.95)	1.06 (-1.90, 4.01)	0.43 (-3.55, 4.41)
E-games	0.18 (-6.16, 6.53)	-2.92 (-13.07, 7.22)	4.81 (-1.06, 10.67)
Computer	-1.56 (-6.58, 3.46)	1.21 (-5.04, 7.45)	-3.40 (-10.78, 3.99)
Total screen	0.33 (-1.55, 2.21)	0.48 (-3.05, 4.01)	0.38 (-2.33, 3.08)
2-5 min bouts			
TV	-0.17 (-0.60, 0.26)	-0.09 (-0.93, 0.76)	-0.24 (-0.73, 0.25)
E-games	0.25 (-0.66, 1.16)	0.58 (-0.70, 1.87)	-0.25 (-1.45, 0.96)
Computer	0.07 (-1.23, 1.38)	0.82 (-0.75, 2.40)	-0.51 (-2.28, 1.25)
Total screen	-0.06 (-0.36, 0.24)	0.10 (-0.54, 0.73)	-0.19 (-0.58, 0.20)
5-10 min bouts			
TV	-0.13 (-0.40, 0.15)	-0.27 (-0.69, 0.16)	-0.03(-0.35, 0.29)
E-games	-0.15 (-0.75, 0.45)	0.16 (-0.86, 1.19)	-0.60 (-1.33, 0.14)
Computer	0.05 (-0.48, 0.59)	-0.20 (-1.03, 0.63)	0.25 (-0.66, 1.15)
Total screen	-0.10 (-0.29, 0.09)	-0.17 (-0.52, 0.18)	-0.05 (-0.28, 0.18)
10-15 min bouts			
TV	-0.04 (-0.14, 0.06)	-0.07 (-0.24, 0.09)	-0.02 (-0.16, 0.11)
E-games	0.06 (-0.20, 0.33)	0.11 (-0.37, 0.59)	0.00 (-0.24, 0.25)
Computer	0.11 (-0.10, 0.33)	0.18 (-0.20, 0.55)	0.06 (-0.26, 0.39)
Total screen	-0.01 (-0.09, 0.07)	-0.02 (-0.20, 0.15)	0.00 (-0.09, 0.08)
≥15 min bouts			
TV	0.00 (-0.06, 0.06)	-0.02 (-0.13, 0.08)	0.02 (-0.07, 0.11)
E-games	0.04 (-0.30, 0.38)	0.17 (-0.36, 0.70)	-0.15 (-0.35, 0.05)
Computer	-0.07 (-0.22, 0.07)	-0.12 (-0.45, 0.21)	-0.04 (-0.30, 0.21)
Total screen	0.00 (-0.06, 0.06)	0.01 (-0.13, 0.15)	0.00 (-0.06, 0.05)

All values are unstandardised β, 95% confidence intervals (CI) after adjusting for average daily accelerometer wear time (mins) and school cluster.

There were no significant associations between time spent in specific SBBs and breaks in and bouts of sedentary time among boys or girls on weekend days (Table 7.14).

Table 7.14 Unstandardised regression coefficients of average weekend day time (hours) spent in specific SBBs and frequency of breaks in and bouts of sedentary time

	All children β (95% CIs)	Boys (n=125) β (95% CIs)	Girls (n=164) β (95% CIs)
Sedentary breaks			
TV	2.2 (-1.12, 5.63)	1.88 (-3.51, 7.27)	3.13 (-1.38, 7.64)
E-games	1.26 (-2.55, 5.07)	2.12 (-1.98, 6.22)	1.27 (-4.42, 6.97)
Computer	-4.21 (-9.89, 1.47)	-4.21 (-14.61, 6.19)	-2.90 (-9.74, 3.94)
Total screen	0.93 (-1.47, 3.34)	1.00 (-2.27, 4.28)	1.51 (-1.37, 4.38)
2-5 min bouts			
TV	0.13 (-0.35, 0.60)	0.32 (-0.43, 1.06)	-0.04 (-0.84, 0.76)
E-games	0.23 (-0.54, 1.00)	-0.01 (-1.03, 1.01)	0.63 (-0.33, 1.06)
Computer	0.80 (-0.73, 2.32)	0.37 (-1.57,2.31)	1.23 (-1.23,3.70)
Total screen	0.19 (-0.19, 0.59)	0.19 (-0.31, 0.69)	0.18 (-0.44, 0.80)
5-10 min bouts			
TV	-0.06 (-0.41, 0.29)	-0.16 (-0.84, 0.52)	0.02 (-0.54, 0.57)
E-games	0.60 (-0.15, 1.36)	0.44 (-0.64, 1.52)	0.86 (-0.11, 1.82)
Computer	0.48 (-0.13, 1.09)	0.69 (-0.19, 1.56)	0.27 (-0.58, 1.12)
Total screen	0.14 (-0.12, 0.39)	0.10 (-0.41, 0.61)	0.17 (-0.23, 0.57)
10-15 min bouts			
TV	-0.07 (-0.25, 0.10)	-0.12 (-0.40, 0.17)	-0.04 (-0.30, 0.21)
E-games	0.17 (-0.02, 0.35)	0.10 (-0.11, 0.32)	0.24 (-0.23, 0.72)
Computer	0.23 (-0.13, 0.59)	0.18 (-0.49, 0.85)	0.24 (-0.10, 0.58)
Total screen	0.02 (-0.10, 0.14)	-0.01 (-0.17, 0.16)	0.04 (-0.15, 0.22)
≥15 min bouts			
TV	-0.06 (-0.16, 0.03)	0.00 (-0.16, 0.15)	-0.13 (-0.27, 0.00)
E-games	-0.04 (-0.18, 0.10)	-0.08 (-0.23, 0.07)	-0.01 (-0.34, 0.32)
Computer	0.04 (-0.17, 0.24)	-0.06 (-0.46, 0.34)	0.09 (-0.25, 0.43)
Total screen	-0.03 (-0.10, 0.03)	-0.03 (-0.10, 0.04)	-0.06 (-0.18, 0.06)

All values are unstandardised ≥, 95% confidence intervals (CI) after adjusting for average daily accelerometer wear time (mins) and school cluster.

7.4.4 Screen time compliance and patterns of sitting time on weekdays and weekend days

There were no significant differences in the percentage of time spent sitting, sit-to-stand transitions or bouts of sitting time among children who exceeded screen time guidelines compared to children who met screen time guidelines (Table 7.15).

Table 7.15 Sitting time (%) and frequency (mean, SD) of sit-to-stand transitions and bouts of sitting time among children who met screen time guidelines compared to children who exceeded screen time guidelines on weekdays and weekend days

	Weekday		Weekend day	
	< 120 mins/day	≥ 120 mins/day	< 120 mins/day	≥ 120 mins/day
All children	69	52	27	86
Sitting time (mean %, SD)	56.7 (9.8)	59.6 (12.4)	55.3 (16.8)	58.8 (13.1)
Sit-to-stand transitions	43.4 (11.4)	44.2 (12.2)	86.1 (25.8)	84.8 (27.3)
2-5 min bouts	8.4 (2.6)	8.9 (2.6)	14.9 (5.1)	14.9 (5.1)
5-10 min bouts	5.7 (1.9)	5.7 (1.8)	9.6 (3.5)	10.2 (3.8)
10-15 min bouts	2.6 (0.9)	2.6 (0.9)	4.4 (2.4)	4.7 (2.5)
≥15 min bouts	2.8 (1.0)	2.9 (1.3)	5.8 (2.9)	6.1 (2.7)
Boys (n)	33	20	10	41
Sitting time (mean %, SD)	57.2 (9.2)	62.8 (14.0)	55.9 (21.8)	59.2 (15.6)
sit-to-stand transitions	42.8 (12.4)	38.1 (10.5)	74.9 (31.5)	82.5 (27.8)
2-5 min bouts	8.5 (2.8)	8.0 (2.3)	13.7 (7.1)	15.4 (6.1)
5-10 min bouts	5.6 (2.2)	4.9 (1.5)	8.2 (4.5)	9.3 (4.1)
10-15 min bouts	2.6 (1.1)	2.3 (0.7)	4.1 (2.2)	4.2 (1.9)
≥15 min bouts	2.9 (1.1)	3.4 (1.2)	5.9 (3.2)	6.0 (2.8)
Girls (n)	36	32	17	45
Sitting time (mean %, SD)	56.2 (10.3)	56.3 (10.7)	54.6 (11.7)	58.3 (10.6)
Sit-to-stand transitions	43.8 (10.6)	48.0 (11.8)	92.8 (20.0)	87.0 (27.0)
2-5 min bouts	8.3 (2.3)	9.5 (2.7)	15.7 (3.5)	15.8 (5.6)
5-10 min bouts	5.7 (1.5)	6.2 (1.9)	10.4 (2.6)	10.9 (3.4)
10-15 min bouts	2.6 (0.7)	2.8 (0.9)	4.6 (2.6)	5.2 (2.9)
≥15 min bouts	2.7 (0.9)	2.6 (1.3)	5.8 (2.8)	6.3 (2.7)

Values represent mean (standard deviation, SD).

7.4.5 Associations between specific SBBs and patterns of sitting time

Weekdays

There were no significant associations between time spent in specific SBBs, total screen time and sitting time on weekdays (Table 7.16).

Weekend days

On weekend days, time spent in TV viewing was significantly and positively associated with sitting time among all children ($p<0.05$). Among girls, TV viewing and total screen time were significantly and positively associated with sitting time ($p<0.05$). There were no significant associations between time spent in specific SBBs, total screen time and sitting time in boys (Table 7.16).

Table 7.16 Unstandardised regression coefficients of average daily time (hours) spent in specific SBBs and average daily sitting time (mins) among boys and girls on weekdays and weekend days

	All children **β (95% CIs)**	**Boys (n=53)** **β (95% CIs)**	**Girls (n=68)** **β (95% CIs)**
Weekday sitting time			
TV	3.21 (-4.35, 10.78)	7.81 (-4.76, 20.39)	0.92 (-7.30, 9.15)
E-games	0.73 (-13.99, 15.45)	-11.22 (-39.21, 16.76)	15.57 (-5.15, 36.30)
Computer	2.55 (-11.32, 16.42)	9.75 (-8.42, 27.92)	-2.24 (-20.14, 15.66)
Total screen	2.28 (-2.29, 6.86)	4.83 (-2.48, 12.15)	1.39 (-4.08, 6.80)
Weekend day sitting time			
TV	**12.95 (1.56, 24.35)***	7.51 (-10.57, 25.59)	**16.33 (0.91, 31.76)***
E-games	3.54 (-21.81, 28.89)	-14.81 (-40.52, 10.91)	45.81 (-6.74, 98.38)
Computer	-8.28 (-38.12, 21.57)	-17.07 (-47.22, 13.07)	-2.98 (-48.06, 42.09)
Total screen	7.45 (-2.39, 17.28)	0.25 (-13.79, 14.29)	**14.02 (1.11, 26.93)***

All values are unstandardised β, 95% confidence intervals (CI) after adjusting for average daily inclinometer wear time (mins) and school cluster.
* $p<0.05$

There were no significant associations between time spent in specific SBBs, sit-to-stand transitions and bouts of sitting time among boys or girls on weekdays (Table 7.17).

Table 7.17 Unstandardised regression coefficients of average weekday time (hours) spent in specific SBBs and frequency of sit-to-stand transitions and bouts of sitting time

	All children β (95% CIs)	Boys (n=53) β (95% CIs)	Girls (n=68) β (95% CIs)
sit-to-stand transitions			
TV	0.04 (-2.03, 2.12)	-1.51 (-5.19, 2.17)	0.73 (-1.57, 3.03)
E-games	1.27 (-3.20, 5.75)	-0.33 (-5.95, 5.29)	2.12 (-5.17, 9.42)
Computer	2.88 (-0.81, 6.57)	1.10 (-3.99, 6.19)	3.68 (-2.38, 9.74)
Total screen	0.34 (-0.65, 1.34)	-0.79 (-2.45, 0.88)	0.81 (-0.80, 2.41)
2-5 min bouts			
TV	0.19 (-0.26, 0.63)	-0.17 (-0.85, 0.51)	0.39 (-0.13, 0.91)
E-games	0.46 (-0.46, 1.38)	-0.08 (-1.37, 1.22)	0.89 (-0.55, 2.33)
Computer	1.16 (0.03, 2.29)	1.12 (-0.29, 2.52)	1.04 (-0.66, 2.75)
Total screen	0.23 (-0.01, 0.48)	0.01 (-0.30, 0.32)	0.35 (-0.01, 0.71)
5-10 min bouts			
TV	-0.11 (-0.40, 0.18)	-0.45 (-1.06, 0.16)	0.11 (-0.28, 0.51)
E-games	-0.02 (-0.81, 0.76)	0.26 (-0.63, 1.14)	-0.37 (-1.54, 0.81)
Computer	0.56 (-0.07, 1.19)	0.19 (-0.72, 1.11)	0.89 (-0.43, 2.21)
Total screen	-0.01 (-0.18, 0.15)	-0.18 (-0.49, 0.12)	0.08 (-0.18, 0.35)
10-15 min bouts			
TV	-0.01 (-0.21, 0.19)	-0.13 (-0.46, 0.21)	0.10 (-0.10, 0.31)
E-games	-0.11 (-0.47, 0.24)	-0.12 (-0.48, 0.23)	-0.07 (-0.64, 0.49)
Computer	0.10 (-0.28, 0.48)	0.14 (-0.30, 0.58)	0.11 (-0.42, 0.64)
Total screen	-0.01 (-0.14, 0.12)	-0.08 (-0.27, 0.12)	0.06 (-0.07, 0.19)
≥15 min bouts			
TV	0.05 (-0.16, 0.27)	0.25 (-0.14, 0.65)	-0.07 (-0.31, 0.18)
E-games	0.02 (-0.37, 0.41)	-0.24 (-0.83, 0.35)	0.35 (-0.35, 1.04)
Computer	-0.18 (-0.66, 0.30)	0.04 (-0.51, 0.60)	-0.34 (-1.12, 0.43)
Total screen	0.02 (-0.09, 0.14)	0.14 (-0.08, 0.36)	-0.04 (-0.19, 0.11)

All values are unstandardised β, 95% confidence intervals (CI) after adjusting for average daily inclinometer wear time (mins) and school cluster.

There were no significant associations between time spent in specific SBBs, sit-to-stand transitions and bouts of sitting time among boys on weekend days (Table 7.18). Among girls, time spent in computer use was significantly and positively associated with the frequency of 5-10 minute bouts (p<0.05), and TV viewing time and total screen time were significantly and positively associated with the frequency of bouts longer than 15 minutes (p<0.01).

Table 7.18 Unstandardised regression coefficients of average weekend day time (hours) spent in specific SBBs, frequency of sit-to-stand transitions and bouts of sitting time

	All children β **(95% CIs)**	**Boys** (n=51) β **(95% CIs)**	**Girls** (n=62) β **(95% CIs)**
sit-to-stand transitions			
TV	0.58 (-2.24, 3.41)	1.76 (-3.74, 7.23)	0.32 (-2.32, 2.95)
E-games	-3.07 (-9.31, 3.17)	-1.03 (-9.28, 7.22)	-5.93 (-15.30, 3.45)
Computer	0.34 (-8.17, 8.84)	5.18 (-8.58, 18.93)	-2.10 (-9.52, 5.32)
Total screen	-0.20 (-2.97, 2.56)	1.10 (-3.12, 5.32)	-0.57 (-2.89, 1.76)
2-5 min bouts			
TV	0.10 (-0.42, 0.62)	0.23 (-1.05, 1.51)	0.12 (-0.47, 0.71)
E-games	-0.29 (-1.70, 1.12)	0.08 (-1.75, 1.91)	-0.80 (-2.87, 1.28)
Computer	0.85 (-1.01, 2.70)	1.71 (-1.55, 4.96)	0.51 (-0.85, 1.88)
Total screen	0.10 (-0.40, 0.60)	0.33 (-0.61, 1.28)	0.05 (-0.34, 0.43)
5-10 min bouts			
TV	0.24 (-0.19, 0.67)	0.54 (-0.30, 1.39)	0.02 (-0.46, 0.50)
E-games	0.35 (-0.57, 1.27)	0.63 (-0.71, 1.98)	-0.22 (-1.28, 0.83)
Computer	**0.99 (0.01, 1.96)***	0.75 (-0.91, 2.41)	**1.74 (0.16, 3.33)***
Total screen	0.30 (-0.04, 0.63)	0.48 (-0.13, 1.09)	0.16 (-0.18, 0.51)
10-15 min bouts			
TV	0.14 (-0.21, 0.50)	0.19 (-0.37, 0.74)	0.14 (-0.35, 0.63)
E-games	0.04 (-0.55, 0.63)	-0.05 (-0.56, 0.47)	0.37 (-1.09, 1.83)
Computer	0.22 (-0.22, 0.66)	0.33 (-0.23, 0.89)	0.32 (-1.01, 1.65)
Total screen	0.10 (-0.16, 0.37)	0.11 (-0.25, 0.47)	0.15 (-0.25, 0.56)
≥15 min bouts			
TV	**0.39 (0.15, 0.63)****	0.20 (-0.20, 0.60)	**0.50 (0.18, 0.81)****
E-games	0.13 (-0.58, 0.84)	-0.32 (-1.16, 0.52)	1.12 (-0.56, 2.78)
Computer	-0.19 (-0.99, 0.61)	-0.56 (-1.46, 0.35)	0.01 (-1.28, 1.30)
Total screen	0.23 (-0.02, 0.48)	0.00 (-0.36, 0.37)	**0.41 (0.12, 0.69)****

All values are unstandardised β, 95% confidence intervals (CI) after adjusting for average daily inclinometer wear time (mins) and school cluster.
* p<0.05, ** p<0.01

7.5 Discussion

The current study examined the association between time spent in specific SBBs, objectively measured total sedentary and sitting time, and the frequency of breaks in and bouts of sedentary and sitting time in 7-10 year old boys and girls. There were no significant differences in total sedentary and sitting time or patterns of sedentary and sitting time between children who met screen time guidelines and children who exceeded screen time guidelines. Playing e-games was significantly and positively associated with sedentary time, and several significant and positive associations were observed between time spent in specific SBBs, total sitting time and bouts of sitting time on weekend days, primarily due to associations among girls.

Apart from the finding that for every one hour increase in playing e-games there was a seven minute increase in time spent sedentary, there were no other significant associations between time spent in specific SBBs and objectively measured sedentary time. Similarly, a study of 10-12 year old European children reported a null association between self-reported TV and computer use and accelerometer measured sedentary time (Verloigne et al. 2013). Conversely, TV viewing was positively associated with sedentary time among 9-10 year old children in the UK SPEEDY study (Kiltsie et al. 2013). In that study monitor wear time was included until 11pm at night and it is plausible that sleep time was captured in the measurement of sedentary time. In the current study, the positive association between e-games and sedentary time may be explained by the higher levels of time spent playing e-games on weekend days. As described in Chapter 4, boys spent more time playing e-games on weekend days than girls. Therefore, it was expected that when analyses were stratified by sex, associations between e-game use and sedentary time would be stronger among boys. However, this was not the case and may be explained by the smaller sample size when analyses were stratified by sex as well as the limited variability in the time spent playing e-games.

In girls, but not boys, each additional hour spent in TV viewing was significantly and positively associated with a 16 minute increase in sitting time on weekend days. There was also a significant and positive association between total screen time and sedentary time; however, it is likely that TV viewing time was driving that association given there were no associations between the other specific SBBs and sitting time.

TV viewing time was associated with a higher frequency of sitting bouts longer than 15 minutes which suggests that in addition to overall higher levels of sitting time there is a greater risk of longer uninterrupted bouts of sitting. As described in Chapter 4 results, TV viewing was the largest contributor to boys' (69%) and girls' (76%) total screen time; however, boys TV viewing time was lower on weekend days and e-game usage was higher compared to weekdays. Although a similar pattern was observed for girls, it was not as marked compared to boys and therefore the results of the current study may reflect consistently high levels of TV viewing in girls on weekend days compared to boys who may engage in other sedentary SBBs. It is interesting that significant and positive associations were observed between TV viewing time, total sitting time and a higher frequency of bouts longer than 15 minutes on weekend days but not weekend days. This finding may reflect a higher concordance between the reported and real time sedentary pursuits during weekend compared with week days.

Strengths and limitations

A key strength of the current study is the use of objective devices to assess sedentary and sitting time. Furthermore, the customised Macro programme enabled specific bout lengths and breaks in and bouts of sedentary and sitting time to be determined. The use of inclinometers in children's sedentary behaviour is relatively new and to the candidates knowledge this is the first study to examine the association between screen time and sitting time. In addition, screen time was assessed separately for boys and girls, on weekdays and weekend days and as separate behaviours (TV, e-games and computer use). However, the small sample size of children with *activ*PAL™ data may have contributed to null associations. Due to the rapid pace of development in new types of electronic media and the ability to engage in multiple types of technology at any one time (Jago et al. 2011) it is possible that the measurement of TV viewing, e-games and computer use may not capture all time spent in specific SBBs.

Conclusion

The results of the current study suggest total screen time and time spent in specific SBBs is not a good indicator of overall sedentary time or patterns of sedentary time, as measured with an accelerometer, in boys or girls on weekdays or weekend days. In contrast, time spent in TV viewing on weekend days may be an indicator of girls who engage in higher levels of sitting time and extended bouts of sitting time on weekend days. This finding may have important implications for health promotion such that simple questions about weekend day TV viewing time may be a suitable proxy to indicate girls who are at increased risk of high levels of sitting time on weekends. However, given the rapid emergence of new screen-based technologies and the opportunity to multimedia task, future research will need to expand the measurements of specific SBBs to reflect this change. Since the findings of the current study suggest that not all screen behaviours are related to total sitting time or patterns of sitting time it will be important to determine whether specific SBBs are related to children's cardiovascular health. Furthermore, although time spent in TV viewing was positively associated with a higher frequency of bouts longer than 15 minutes further research is needed to ascertain the importance of patterns of sedentary behaviour to children's health using objective devices.

Chapter 8
The association between children's screen-based behaviours and cardiovascular risk factors

8.1 Introduction

SBBs are key children's sedentary leisure time pursuits. Approximately three-quarters of Year 3 children in the Transform-Us! study (Chapter 4) exceeded the current national screen time recommendation of limiting the use of electronic media for entertainment to no more than 2 hours per day (The Department of Health 2014). The importance of time spent in screen-based pursuits to CVD risk factors is therefore particularly concerning given that the prevalence of childhood obesity is as high as 30% in many industrialised countries (Wang & Perry 2006) and there is emerging evidence that other CVD related risk factors (e.g. lipid profiles and blood pressure) are elevated at an early age (Ekelund et al. 2009).

As discussed in Chapter 2, evidence of the detrimental effects of screen time to cardiovascular health in children is largely based on studies of total screen time or TV viewing, and the association with adiposity (Tremblay et al. 2011). Few studies have considered the relevance of screen time to CVD risk factors, such as blood pressure (Ekelund et al. 2006; Hee-Taik et al. 2010; Lazarou, Panagiotakos & Matalas 2009; Martinez-Gomez, Tucker, et al. 2009; Pardee et al. 2007; Wells et al. 2008) and lipids (Carson & Janssen 2011; Ekelund et al. 2006; Hee-Taik et al. 2010; Martinez-Gomez et al. 2010) in primary school aged children. Overall, evidence of associations between screen time and CVD risk factors is inconclusive, largely due differences in the way in which screen time is defined as well as inconsistencies in controlling for important confounders.

Few studies have considered the differential health effects associated with what may be considered as passive (TV viewing) compared to interactive SBBs, such as playing e-games and using a computer (Rey-Lopez et al. 2008). Differentiation between different types of SBBs is important because interactive SBBs may have metabolic effects that are not comparable to that of watching TV (Wang & Perry 2006) and may have different behavioural mediators, such as snacking (Pearson & Biddle 2011).

Time spent in MVPA and dietary factors are established influences on cardiovascular health (see section 2.2). To identify the independent association between screen time and CVD risk factors it is important to adjust for these confounders, yet few studies have done this. Furthermore, being overweight or obese increases the likelihood of additional CVD risk factors, including elevated blood pressure and an adverse lipid profile (Stanner 2005). A critical gap in the literature, therefore, is evidence of the association between different types of SBBs and CVD risk factors that is independent of MVPA, diet and adiposity.

8.2 Aim

The aims of this chapter are to:

1. Describe the prevalence of CVD risk factors (adiposity, lipids, blood pressure) among a sample of Year 3 Australian boys and girls; and
2. Examine the cross-sectional associations between average daily time spent in specific SBBs (watching TV, playing e-games, computer use, and overall screen time), CVD risk factors and clustered CVD risk among a sample of Year 3 Australian boys and girls.

8.3 Methods

8.3.1 Procedures

The current study utilised baseline data from the Transform-Us! study, including children's screen time, cardiovascular health measures (BMI, WC, blood pressure and lipid markers), MVPA , dietary intake and parent education. The procedures for the collection of these measures are described in detail in section 3.7 and summarised below.

Briefly, time spent in TV viewing, e-games and computer use was obtained by parent-proxy report (Appendix C.3). Height, weight, WC and blood pressure were measured by trained research staff at the child's school. A subsample of children (n=219) provided a fasted morning blood sample at a local pathology clinic for biochemical analysis of HDL-C, LDL-C, TC and TG. Parents completed a survey which obtained information on their highest level of education (used as an indicator of socioeconomic status) and the usual weekly frequency (during the previous month) of their child's consumption of key energy dense sweet and savoury snack foods, fast foods and sweetened drinks which were used to provide a measure of diet energy density. ActiGraph accelerometer time (average minutes per day) spent in MVPA and accelerometer average daily wear time were used as covariates in the current study. Children were instructed to wear the accelerometer for eight consecutive days on a belt positioned over the right hip during waking hours and to remove the accelerometer during water-based activities (e.g. bathing and swimming).

8.3.2 Data management

Specific SBBs and total screen time

A detailed description of the data management procedures for TV/video/DVD viewing, e-games (PlayStation © and computer games), computer and internet use (excluding computer games) and total screen time is presented in section 3.8.3.

Cardiovascular health measures

The data management procedures for the anthropometric measures (height, weight, WC), blood pressure (DBP and SBP) and blood lipids (TC, HDL-C, LDL-C, TG), and definitions of risk are described in section 3.8.4. A continuously distributed clustered CVD risk score was derived using the sum of the values of SBP, DBP, LDL-C, inverted HDL-C, TG and WC, expressed as z-scores.

For analysis of the association between screen time variables and CVD risk factors, only children with a complete data set for the covariates, and the cardiovascular health outcomes were included (170 children were excluded due to missing data)

Diet energy density

The data collection procedures for the parent proxy-report of children's individual food and beverage consumption items (Appendix C.5) are described in section 3.7.5. Parents reported the child's consumption of key energy dense foods (salty snacks, chocolate and sweets, cakes, pastries, fast food, chips) on a nine point scale, and beverages (fruit juice and soft drink) on an eight point scale. A diet energy density score was created using the sum of the scores (described in section 3.8.3).

MVPA

MVPA (mins/day) was calculated using age-adjusted cut-points (Freedson, Pober & Janz 2005) defined as ≥4 METs (Trost et al. 2011).

8.3.3 Data analyses

Analyses were undertaken with Stata/SE version 12 (StataCorp 2011). The distribution of each of the outcome variables were assessed for normality. Since BMI was positively skewed, age and sex adjusted BMI z-scores (Cole et al. 2000) were calculated and used in all analyses. Descriptive data (mean, SD) were calculated for CVD risk factors and independent t-tests were undertaken to describe differences between boys and girls on these risk factors (Table 8.19).

Forced entry linear regression models were used to examine the association between average daily time (hours/day) in TV viewing, e-games, computer use, total screen time (i.e. summed daily time in TV, e-games & computer use), and CVD risk factors and clustered CVD risk. Four statistical models were used to explore the associations; Model 1 adjusted for school clustering, sex of the child (except for BMI z-score) and parent education; Model 2 additionally adjusted for MVPA and accelerometer wear time; Model 3 additionally adjusted for diet energy density composite score; and where adiposity was not the outcome of interest Model 4 additionally adjusted for WC.

There were no differences in the anthropometric and SBP or DBP measures between children who provided a blood sample and those who did not ($p>0.1$); therefore all children with a valid measure of screen time, all covariates and at least one CVD risk factor were included in analyses. In addition, children included in the analysis of screen time and clustered CVD risk were required to have each of the subcomponents of the score (i.e. WC, SBP, DBP, HDL-C, LDL-C and TG) which resulted in an extra 117 children excluded from that part of the analysis.

8.4 Results

8.4.1 Sample characteristics and CVD risk factors

The characteristics of the children and the number of children providing complete data for each variable are shown in Table 8.19. The mean age was 8.7 (0.4) years and approximately half of the parents had completed a university degree. Nearly 60% of children exceeded screen time recommendations of ≥120 minutes per day. Approximately one in five children were classified as overweight or obese based on BMI (Table 8.20). A high percentage of children had elevated TC levels (37.5%); however, only two children had HDL-C below the 10^{th} percentile. Seventeen percent of the children had a SBP or DBP greater than the 90^{th} percentile. There were no differences in the non-blood health measures between children who provided a blood sample and children who did not provide a blood sample (p>0.05).

Table 8.19 Participant characteristics

Measures	Valid (n)	Mean (SD)
Age	264	8.7 (0.4)
Parent education (% university)	264	46.2
Accelerometer variables		
MVPA (mins/day)	264	66.9 (19.5)
Accelerometer wear time (mins/day)	264	699.0 (53.5)
Specific SBBs		
TV (mins/day)	262	101.5 (56.1)
E-games (mins/day)	264	25.4 (32.9)
Computer (mins/day)	263	19.6 (21.8)
Total screen (mins/day)	261	146.4 (78.9)
Screen time ≥ 120 mins/day (%)	261	58.6
Diet		
Diet composite score	264	21.0 (5.1)
Health measures		
Height (cm)	263	132.0 (6.5)
Weight (kg)	263	30.0 (6.1)
BMI (kg/m^2)	263	17.1 (2.5)
BMI *z*-score	263	0.2 (0.9)
WC (cm)	264	59.1 (6.3)
SBP (mmHg)	255	101.7 (9.2)
DBP (mmHg)	255	60.1 (8.02)
TC (mmol/L)	147	4.59 (0.78)
HDL-C (mmol/L)	147	1.69 (0.33)
LDL-C (mmol/L)	147	2.58 (0.73)
TG (mmol/L)	147	0.69 (0.25)
Clustered CVD risk^	147	-0.29 (2.7)

Abbreviations: WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; TG, triglycerides.

^ Standardised and sum of WC, the average of SBP and DBP, LDL-C, inverted HDL-C and TG.

Table 8.20 Percentage of children with elevated levels of CVD risk factors

CVD risk factor	Valid (n)	%
BMI (>25 kg/m2)	263	22.1
WC ≥75th percentile	264	30.7
DBP and/or SBP >90th percentile to <95th percentile	255	6.6
DBP and/or SBP ≥95th percentile	255	10.5
TC >90th percentile	147	37.5
HDL-C <10th percentile	147	1.4
LDL-C >90th percentile	147	12.9
TG ≥90th percentile	147	19.7

Abbreviations: BMI, body mass index;
WC, waist circumference; SBP, systolic blood pressure;
DBP, diastolic blood pressure; TC, total cholesterol;
HDL-C, high density lipoprotein cholesterol;
LDL-C, low density lipoprotein cholesterol; TG, triglycerides.

8.4.2 Associations between time spent in TV, computer use, e-games, total screen time and CVD risk factors among Year 3 children

TV viewing

Results from the linear regression models found that TV viewing time was positively associated with BMI z-scores ($p<0.01$) and WC ($p<0.05$) after adjusting for sex of the child, SES, MVPA, accelerometer wear time and diet energy density (Table 8.21). A significant positive association was also found between TV viewing time and SBP ($p<0.05$) after adjusting for all covariates.

E-games

Time spent playing e-games was positively associated with LDL-C ($p<0.05$) in the fully adjusted model (Table 8.21). There was no association between e-games and any of the other cholesterol and lipid measures, BP, adiposity or clustered CVD risk score in any of the models.

Computer use

Time spent using a computer was not associated with any of the CVD risk factors or clustered CVD risk score in any of the models (Table 8.21).

Total screen time

Average daily total screen time was positively associated with BMI z-scores ($p<0.05$) in the fully adjusted model (Table 8.21). No associations were observed between total screen time and lipids, blood pressure or clustered CVD risk score in any of the models.

Table 8.21 Unstandardized regression coefficients of time (hours/day) spent in screen-based behaviours and CVD risk factors

	TV β (95% CI)	E-games β (95% CI)	Computer β (95% CI)	Total screen β (95% CI)
Adiposity (n=263)				
z-BMI score				
Model 1	**0.22 (0.08, 0.34)****	0.00 (-0.29, 0.28)	-0.18 (-0.50, 0.14)	**0.10 (0.01, 0.19)***
Model 2	**0.22 (0.09, 0.36)****	-0.01 (-0.28, 0.26)	-0.18 (-0.49, 0.14)	**0.10 (0.01, 0.19)***
Model 3	**0.25 (0.10, 0.39)****	0.00 (-0.29, 0.28)	-0.17 (-0.49, 0.14)	**0.12 (0.02, 0.21)***
WC (cm)				
Model 1	**1.18 (0.09, 2.26)***	-0.05 (-2.08, 1.98)	-0.74 (-3.08, 1.61)	0.57 (-0.20, 1.33)
Model 2	**1.24 (0.14, 2.34)***	-0.16 (-2.06, 1.73)	-0.67 (-2.96, 1.62)	0.58 (-0.16, 1.33)
Model 3	**1.42 (0.29, 2.55)***	0.01 (-2.12, 2.15)	-0.61 (-2.84, 1.61)	0.71 (-0.08, 1.51)
Blood pressure (n=255)				
SBP (mm Hg)				
Model 1	**1.82 (0.23, 3.40)***	-1.22 (-3.72, 1.27)	1.76 (-2.10, 5.63)	0.86 (-0.36, 2.07)
Model 2	**1.84 (0.23, 3.45)***	-1.32 (-3.86, 1.20)	1.79 (-2.17, 5.74)	0.85 (-0.37, 2.07)
Model 3	**1.83 (0.18, 3.49)***	-1.71 (-4.14, 0.72)	1.69 (-2.16, 5.55)	0.81 (-0.41, 2.04)
Model 4	**1.52 (0.00, 3.04)***	-1.74 (-4.04, 0.56)	1.88 (-1.90, 5.67)	0.60 (-0.58, 1.79)
DBP (mm Hg)				
Model 1	0.54 (-0.78, 1.87)	-0.55 (-3.18, 2.07)	0.80 (-1.95, 3.54)	0.28 (-0.76, 1.31)
Model 2	0.63 (-0.77, 2.03)	-0.89 (-3.32, 1.54)	0.91 (-1.90, 3.72)	0.27 (-0.79, 1.33)
Model 3	0.60 (-0.92, 2.11)	-1.08 (-3.59, 1.44)	0.87 (1.96, 3.71)	0.23 (-0.91, 1.38)
Model 4	0.38 (-1.14, 1.91)	-1.09 (-3.66, 1.47)	0.99 (-1.81, 3.78)	0.10 (-1.07, 1.28)
Cholesterol and Lipids (n=147)				
HDL-C (mmol/L)				
Model 1	0.00 (-0.06, 0.06)	-0.06 (-0.14, 0.01)	-0.10 (-0.08, 0.28)	0.00 (-0.39, 0.04)
Model 2	-0.01 (-0.06, 0.06)	-0.04 (-0.11, 0.02)	0.09 (-0.12, 0.29)	0.00 (-0.04, 0.04)
Model 3	-0.01 (-0.06, 0.05)	-0.04 (-0.12, 0.03)	0.09 (-0.11, 0.29)	0.00 (-0.04, 0.04)
Model 4	0.03 (-0.02, 0.07)	-0.03 (-0.10, 0.04)	0.06 (-0.13, 0.24)	0.01 (-0.02, 0.05)

Table 8.21 continued

	TV β (95% CI)	E-games β (95% CI)	Computer β (95% CI)	Total screen β (95% CI)
LDL-C (mmol/L)				
Model 1	0.01 (-0.12, 0.13)	0.12 (-0.02, 0.27)	-0.04 (-0.35, 0.28)	0.02 (-0.06, 0.10)
Model 2	0.02 (-0.10, 0.13)	0.09 (-0.04, 0.24)	-0.01 (-0.32, 0.30)	0.02 (-0.05, 0.10)
Model 3	0.03 (-0.08, 0.14)	**0.13 (0.01, 0.25)***	0.00 (-0.32, 0.33)	0.04 (-0.04, 0.11)
Model 4	0.00 (-0.10, 0.10)	**0.11 (0.00, 0.22)***	0.04 (-0.28, 0.35)	0.02 (-0.05, 0.09)
TC (mmol/L)				
Model 1	0.02 (-0.09, 0.12)	0.05 (-0.10, 0.20)	0.04 (-0.31, 0.40)	0.03 (-0.05, 0.10)
Model 2	0.02 (-0.08, 0.13)	0.03 (-0.12, 0.17)	0.07 (-0.27, 0.41)	0.03 (-0.04, 0.10)
Model 3	0.04 (-0.05, 0.13)	0.05 (-0.9, 0.18)	0.09 (-0.26, 0.43)	0.04 (-0.02, 0.11)
Model 4	0.05 (-0.04, 0.13)	0.04 (-0.11, 0.18)	0.09 (-0.27, 0.44)	0.05 (-0.01, 0.11)
Triglycerides (mmol/L)				
Model 1	-0.01 (-0.06, 0.04)	0.05 (-0.3, 0.14)	-0.07 (-0.18, 0.04)	0.00 (-0.04, 0.03)
Model 2	0.00 (-0.05, 0.04)	0.04 (-0.06, 0.13)	-0.06 (-0.18, 0.07)	0.00 (-0.03, 0.03)
Model 3	0.00 (-0.04, 0.04)	0.05 (-0.05, 0.14)	-0.05 (-0.17, 0.07)	0.00 (-0.03, 0.03)
Model 4	-0.01 (-0.06, 0.03)	0.04 (-0.05, 0.13)	-0.04 (-0.16, 0.07)	0.00 (-0.31, 0.03)
CVD risk score^				
Model 1	0.28 (-0.35, 0.91)	0.61 (-0.24, 1.45)	-0.86 (-2.24, 0.51)	0.17 (-0.25, 0.59)
Model 2	0.37 (-0.23, 0.96)	0.38 (-0.36, 1.12)	-0.66 (-2.14, 0.81)	0.19 (-0.21, 0.59)
Model 3	0.46 (-0.17, 1.10)	0.55 (-0.18, 1.29)	-0.58 (-2.06, 0.89)	0.28 (-0.16, 0.71)

β = beta coefficient. Model 1 adjusted for school clustering, sex of the child and SES: Model 2, additionally adjusted for MVPA and accelerometer wear time; Model 3, additionally adjusted for a diet composite score; Model 4, additionally adjusted for waist circumference.

Abbreviations: SBP indicates systolic blood pressure; DBP, diastolic blood pressure; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; TC, total cholesterol.

^ Standardized and sum of waist circumference, the average of SBP and DBP, LDL-C, inverted HDL-C and triglycerides.

8.5 Discussion

The main findings from this cross-sectional study, examining the association between children's daily engagement in specific SBBs, total screen time and CVD risk factors, were that: TV viewing was positively associated with adiposity (BMI z-score and WC) and SBP, independent of potential confounders. However, playing e-games, computer use and total screen time were not associated with any CVD risk factors or clustered CVD risk score, with the exception of a positive association between e-games and LDL-C and total screen time and BMI.

Consistent with a number of previous cross-sectional studies in children (Andersen et al. 1998; Crespo et al. 2001; Dowda et al. 2001; Ekelund et al. 2006; Hesketh et al. 2007), TV viewing time was positively associated with adiposity. However, a distinctive aspect of the current study is the adjustment for objectively measured MVPA and diet. That is, in the fully adjusted model there was a 0.25 increase in BMI z-score and 1.42cm greater WC for every one hour increment in TV viewing after adjusting for all covariates. While several previous studies have observed no association between TV viewing and adiposity, (Fairclough et al. 2009; Graf et al. 2004; Vandewater, Shim & Caplovitz 2004) comparability with these studies is difficult due to a lack of adjustment for covariates (Fairclough et al. 2009; Graf et al. 2004) and differences in the measurement of TV viewing time [e.g. time use diaries (Vandewater, Shim & Caplovitz 2004), self-reported time per day using a Likert scale (Fairclough et al. 2009), and self-reported number of days per week watching TV (Graf et al. 2004).

When all SBBs were combined as a measure of total screen time there was no significant association with WC and the relationship with BMI z-score was weaker than the association between TV viewing time alone and BMI z-score. A similar result was reported in a study of 2-15 year olds (Fulton et al. 2009) whereby combining computer use with TV viewing was less strongly associated with BMI compared to TV viewing alone. In the current study, it is likely that the positive association between total screen time and BMI was driven by TV viewing time given that the daily time engaged in e-games and computer use accounted for less than a third of total screen time and these behaviours were not individually associated with any measure of adiposity. It has been suggested that single markers, such as TV viewing, are unlikely to explain relationships between sedentary behaviour and health (Marshall et al. 2004). However, the findings of the current study suggest that some, but not all SBBs, are related to CVD risk factors among children, and therefore the combination of SBBs as a measure of total screen time may not represent an ideal measure when examining important health associations of specific behaviours.

TV viewing time was significantly and adversely associated with SBP, independent of potential confounders. For every one hour increment in TV viewing time, there was a 1.52 mmHg higher SBP. While this finding is consistent with previous studies of TV viewing time and blood pressure in children (Lazarou, Panagiotakos & Matalas 2009; Martinez-Gomez, Tucker, et al. 2009), comparability between studies is difficult because most failed to adjust for adiposity (Martinez-Gomez, Tucker, et al. 2009) and none adjusted for a measure of diet energy density or MVPA. Conversely, the EYHS study of children and adolescents reported no association between TV viewing and SBP before or after adjusting for MVPA (average daily counts per minute) and adiposity (Ekelund et al. 2006). However, in that study TV viewing was only measured on weekdays which may have resulted in an underestimation of total TV viewing time, and blood pressure was only measured on one occasion which limits the accuracy of the measurement used in analysis. It is interesting that TV viewing, but no other sedentary SBBs, were associated with elevated SBP. However, although diet energy density was adjusted for in the current study, snacking during TV viewing was not specifically assessed and may be an important mediator that is relevant to TV viewing but no other SBBs.

With the exception of a positive association between e-games and LDL-C, no associations between any of the other individual SBBs or total screen time and cholesterol or lipid concentrations were observed. In contrast, the findings from a study using NHANES data (Carson & Janssen 2011) revealed a positive association between TV viewing and non HDL-C. However, it is difficult to compare those results because maturation influences lipid concentrations (Daniels & Greer 2008) and maturity status was not adjusted for despite the assessment of adolescents in that study. The finding that time spent playing e-games was positively associated with LDL-C could be explained by observations from previous research in which children who spent extended time playing e-games were significantly less active (Salmon et al. 2005). Although MVPA was adjusted for in the current study, it may be that the time spent in light-intensity activities, which have been shown to be beneficial to health (Healy et al. 2007), was lower among children who spent more time in e-games.

There was no association between any of the SBBs or total screen time and CVD risk score. This contrasts with the findings from the EYHS (Ekelund et al. 2006) and NHANES (Carson & Janssen 2011) studies which reported positive associations between TV viewing and clustered metabolic risk. However, comparability in the outcome is limited because the components of the risk score differed between studies with the EYHS including insulin and glucose and NHANES including an inflammatory marker, C-reactive protein. Inflammatory markers are suggested to have greater sensitivity and utility, compared to traditional risk factors (Balagopal et al. 2011). Therefore, the null association observed in the current study may be due to a lack of sensitivity in the composite score or it may reflect a relatively healthy sample with regard to the CVD risk factors measured.

Strengths and limitations

The main strengths of the current study are the adjustment for key confounding factors, notably objectively-assessed MVPA, diet energy density, SES, and WC (where adiposity was not the outcome). A second key strength is that TV viewing, e-games and computer use were analysed as separate behaviours and in combination. This is important as not all screen time may be equal and different behaviours may have different health implications. As discussed in Chapter 2 there are well known limitations with proxy-report questionnaires, including the likelihood that the respondent has not observed all of the time the child has spent in TV viewing, e-games and computer use, and may report socially desirable responses. While screen time was assessed by proxy report, the questionnaire has acceptable reliability and validity (Salmon et al. 2008). Additionally, as described in Chapter 4, there has been a rapid emergence of new electronic media technologies such as e-readers, tablet computers and smart phones. Therefore, TV viewing, computer use and playing e-games do not represent all SBBs and total screen time may have been underestimated. Furthermore, self-selection bias may also be a factor in the current study whereby children who are overweight or obese may have chosen not to participate in the study. Consequently the study sample may comprise a greater proportion of 'healthy' children compared to the Australian population, although the percentage of overweight and obesity was only marginally lower compared to recent population estimates in Australia (Australian Bureau of Statistics 2013b). A composite score of CVD risk was used because this measure may account for day-to-day fluctuations that can occur with single markers (Andersen et al. 2006). However, markers of insulin and inflammation were not included which may reduce the sensitivity of the measure to CVD risk. Lastly, time spent in TV viewing, e-games and computer use was only measured at one time point. This may not provide an accurate snapshot of overall or long term engagement in SBBs and due to the cross-sectional nature of the study causality cannot be established.

Conclusion

In this sample of Australian primary school children aged 7 to 10 years, adverse associations were found for TV viewing with adiposity and SBP, and for e-games with LDL-C, independent of important confounders. However, no associations with CVD risk factors were observed when all behaviours were combined as a measure of total screen time. Although each of the SBBs measured are typically performed while sitting, the associations with children's health appears to differ by the type of SBB, suggesting that the health mechanisms may be behaviourally mediated. Computer use was not adversely associated with CVD risk factors in this age group. However, among older children, who have had longer life exposure, computer use may be adversely associated with CVD risk factors. Public health strategies and interventions which aim to reduce CVD risk factors in children may need to consider targeting different SBBs. In addition, clear distinction between types of SBBs appears to be an important consideration for future research. The results presented in Chapter 7, however, suggest that screen time is not a good indicator of total sedentary time or patterns of sedentary time. Therefore, the proceeding chapter builds on the contextual findings presented in this chapter by examining the association between objectively measured prevalence and patterns of sedentary time and CVD risk factors among children.

Chapter 9
The association between objectively measured patterns of sedentary time and cardiovascular risk factors

9.1 Introduction

The association between sedentary behaviour and CVD risk factors in children is usually measured by self- or proxy-reported time spent in specific SBBs due to the relative ease of administration of questionnaires (Loprinzi & Cardinal 2011). While it is important to understand the impact of such prevalent behaviours on health, the total time spent in SBBs may not represent all of children's accumulated sedentary time (Verloigne et al. 2013). This was highlighted in Chapter 7 where there was limited evidence to suggest that time spent in SBBs is associated with the total volume of time spent sedentary.

As discussed in section 2.8.1 (Appendix B.1), evidence of adverse associations between total sedentary time and CVD risk is limited with many studies reporting null relationships (e.g. Carson, Stone & Faulkner et al. 2014; Carson and Janssen 2011; Ekelund et al. 2012). However, positive associations have also been reported (Chinapaw et al. 2012; Coley et al. 2013). An important consideration is that few studies have statistically controlled for both MVPA and diet (Carson & Janssen 2011; Cliff et al.2013). In addition, comparisons between studies are difficult because of variations in accelerometer data management, such as the cut-point applied to define sedentary time, the definition of non-wear time, the criteria for a valid day, and the epoch length used (Cain et al. 2013). Furthermore, variations in the measurement of health outcomes (e.g. different measures of adiposity, the number of blood pressure measures taken, and whether blood samples were fasted) limits comparability between the studies. Lastly, a wide age range is evident in these studies. It may be that older children, who have had longer life time exposure to sedentary behaviour as well as a greater time frame for the development of CVD risk factors, are more likely to exhibit CVD risk factors.

With a new inclusion that recommends breaking up prolonged periods of sitting, the recently updated Australian Physical Activity Guidelines reflects an increase in public health awareness of the importance to not only reduce time spent sedentary but also to break up sedentary time (The Department of Health 2014). The advancement of these guidelines to encompass breaks in sitting is not surprising because in adult cohorts, significant and positive beneficial associations between increased breaks in sedentary time and cardio-metabolic risk factors have been reported in both observational (Healy et al. 2008; Healy et al. 2011) and intervention studies (Dunstan et al. 2012). However, while these studies have examined the relevance of breaking up sedentary time to adult health there is no consensus on the point at which the duration of a ‘prolonged bout’ is detrimentally associated with CVD health.

Few studies have examined cross-sectional associations between sedentary breaks, bouts and CVD risk factors in children and adolescents and these studies have reported null (Carson & Janssen 2011; Colley et al. 2013) or minimal associations with bout durations less than 10 minutes (Carson, Stone & Faulkner 2014). However, as discussed in the literature review (section 2.6.1) the bout duration of studies by Carson and Colleagues (2011) and Colley and colleagues (2013) was limited to 30 minutes or more to represent the length of a typical TV programme and a 20% allowance of counts above 100 (Carson & Janssen 2011) and 20-120 minutes with a 20% allowance of counts above the 100 cpm cut-point, not including MVPA, was applied to replicate real world situations (Colley et al. 2013). The ‘forgiveness’ rule applied in both these studies is problematic because light-intensity activity and breaks in sedentary time, which have been reported to be beneficial to health (Healy et al. 2007; Healy et al. 2008), may be included in the bout.

As described in Chapter 6, children in the Transform-Us! study had a higher frequency of shorter bouts of 2-5, 5-10 and 10-15 minutes compared to bouts of longer duration (≥15 minutes). Consequently, research is needed to examine associations between more prevalent sedentary bout lengths and CVD risk factors in children. It could be argued that if long bouts are detrimental to health, shorter bouts may be beneficial to health because they may reflect more frequent interruptions to sedentary time, though this has yet to be examined. To the candidate’s knowledge, no evidence is currently available regarding the association between patterns of accumulated sedentary time (i.e. breaks and sustained bouts) and CVD risk factors in Australian children.

9.2 Aim

The aim of this chapter is to examine the cross-sectional associations between the average total daily sedentary time, patterns of sedentary time (breaks and bouts) and CVD risk factors in 7-12 year old Australian children.

9.3 Methods

9.3.1 Procedures

Data were drawn from children aged 7 to 12 years participating in the Transform-Us! Study (Salmon et al. 2011) and the LOOK study (Telford et al. 2009). The data collection procedures are described in detail in Chapter 3 and summarised below.

Children from the Transform-Us! and LOOK studies were fitted with an ActiGraph accelerometer (GT3X and GT1M, respectively) by a trained research assistant. These monitors have acceptable comparability (Robusto & Trost 2012) and data were pooled for the current study. Instructions were provided to wear the ActiGraph on a belt positioned over the right hip and to remove it during water-based activities, such as swimming and bathing, as well as contact sports if needed.

Family demographic information, including parent age, education and country of birth, was obtained by a questionnaire which was completed by a parent or carer of the child in the Transform-Us! (Appendix C.4) and LOOK (Appendix D.3) studies. Information on the child's usual consumption of energy dense foods and sweetened beverages was collected using the parent questionnaires.

Height, weight, WC and blood pressure were measured at the child's school by trained research staff. Children who had informed written parental consent to participate in the biochemical (blood) analysis attended a local pathology clinic to provide a fasted morning blood sample. Children from the LOOK study attended the Canberra Hospital during school hours and DXA scanning was undertaken by a trained technician to assess total body fat percent.

9.3.2 Data management

ActiGraph data reduction

The management of ActiGraph data is described in detail in section 3.8.1. Briefly, data were downloaded in 15-second epochs using Actilife Monitoring System, Version 5.1. Non-wear time was defined as 20 minutes or more of consecutive zero's (Cain et al. 2013) and wear time was calculated by subtracting non-wear time from the total waking day (i.e. 6am-10pm). A valid weekday and weekend day was considered to be ≥480 minutes and ≥420 minutes of wear time, respectively. Participants were required to have at least 3 valid weekdays and one valid weekend day to be included in analyses (n=490).

Sedentary time variables

As described in section 3.8.1, the raw files were processed with a customised Excel Macro programme to generate total sedentary time, breaks in and bouts (2-5, 5-10, 10-15, ≥15 minutes) of sedentary time. The first complete 15-second epoch of sedentary time (i.e. ≤25 counts/15s) defined the beginning of a sedentary bout and the last consecutive sedentary epoch defined the end of a sedentary bout. A sedentary break was defined as an interruption in sedentary time in which the counts changed from ≤25 counts to >25 counts between consecutive epochs. There was no provision of a forgiveness rule of counts above the sedentary threshold.

Cardiovascular health measures

The data management procedures for the anthropometric measures (height, weight, WC and % body fat), blood pressure (DBP and SBP) and blood lipids (TC, HDL-C, LDL-C, TG), and definitions of risk are described in Chapter 3 (section 3.8.4). A continuously distributed clustered CVD risk score was derived by standardising and summing WC, SBP and DBP, LDL-C, inverted HDL-C and triglycerides. A complete set of each of these CVD risk factors was required to be included in the analysis of clustered CVD risk (i.e. WC, SBP, DBP, HDL-C, LDL-C & TG). Therefore, 138 children with valid accelerometer wear time were excluded due to missing data.

For the analysis of the association between sedentary time variables and CVD risk factors, only children with valid wear time (as described above), a complete data set for the covariates, and the respective cardiovascular health outcome were included. There were no significant differences in the non-blood health measures between children who provided a blood sample and children who did not provide a blood sample ($p>0.1$).

MVPA

MVPA (mins/day) was calculated using age-adjusted cut-points (Freedson, Pober & Janz 2005) defined as $\geq$ 4 METs (Trost et al. 2011).

Diet energy density

The data management of the parent proxy-report of children's individual food and beverage items for Transform-Us! (Appendix C.5) and LOOK (Appendix D.4) are described in section 3.8.3. As the questionnaire items differed between the two studies, a standardized diet energy density z-score was created using the sum of the scores.

Age

Parents reported the date of birth of their child in the parent questionnaire (section 3..4). Age was calculated as the total years and months between the first school visit for that child and their date of birth.

9.3.3 Data analyses

All analyses were undertaken using Stata/SE version 12 (StataCorp 2011). Independent sample t-tests and Pearson's chi-square were undertaken to describe differences between Transform-Us! and LOOK study participants in ActiGraph variables and CVD health characteristics. The distributions of each of the outcome variables were assessed for normality. BMI was positively skewed, therefore age and sex adjusted BMI z-scores (Cole et al. 2000) were calculated and used in all analyses.

Forced entry linear regression models were used to examine the association between total volume of sedentary time (hours/day), the frequency of average daily breaks in sedentary time and the frequency of average daily bouts of sedentary time with CVD risk factors and clustered CVD risk. Four statistical models were used to examine associations between the independent variables and CVD health outcomes: Model 1 adjusted for school clustering, sex of the child (except for BMI z-score), age and accelerometer wear time; Model 2 additionally adjusted for MVPA (average minutes/day); Model 3 additionally adjusted for diet energy density composite score; and Model 4 additionally adjusted for WC where adiposity was not the outcome of interest. Parent education was not correlated with the outcome measures ($p>0.1$) so was not included as a covariate.

Due to the wider age range of children included in this chapter (7-12 years), post hoc analysis of the potential effect modification of age (months) on the observed associations was examined by using appropriate interaction terms and these are presented in Appendix E.3. These interaction terms were determined for sedentary time and breaks in and bouts of sedentary time, and were added separately into the analyses to determine their effect on each of the health outcomes. Statistical significance for the interaction terms was set at $p<0.1$.

9.4 Results

9.4.1 Characteristics of the study participants

The characteristics of the children from the Transform-Us! and LOOK studies and the number of children providing complete data for each variable are shown in Table 9.22. The mean age of participants in the LOOK study (12.0 [0.3] years) was significantly higher than the mean age of participants in the Transform-Us! study (8.8 [0.4] years; $p<0.001$). A higher percentage of parents from the Transform-US! study (46.6%) had a university degree compared to parents of participants in the LOOK study (33%; $p<0.001$). Participants in the Transform-

Us! study spent significantly more time (%) per day in MVPA (10.9 [2.8]) compared to children in the LOOK study (6.9 [2.4]) and less time (%) sedentary per day (58.8 [57.5] vs, 63.4 [5.4] respectively).

As described in Table 9.23, the percentage of children classified as overweight or obese as measured by BMI and WC was higher in the LOOK study group (25.9%, 35.9% respectively) compared to participants in the Transform-Us! study (22.1%, 19.8% respectively; $p<0.05$ and 0.001). A significantly higher percentage of participants in the LOOK study had SBP or DBP >90th percentile (22.1%) compared to participants in the Transform-Us! study (19.6%, $p<0.05$). There was a significantly higher percentage of participants with HDL-C below the 10th percentile and LDL-C above the 90th percentile among participants in the LOOK study (7.1%, 17.6% respectively) compared to participants in the Transform-Us! study group (0.8%, 13.7% respectively; $p<0.001$).

Table 9.22 Characteristics of children in the Transform-Us! and LOOK studies

	Transform-Us!		LOOK	
Measures	**Valid (n)**	**Mean (SD)**	**Valid (n)**	**Mean (SD)**
Age	264	8.8 (0.4)	129	12.0 (0.3)†
Parent education (% university)	264	46.6	78	33.0*
Accelerometer variables				
Wear time (mins/day)	264	572.3 (85.7)	129	742.2 (60.6)†
MVPA (Mean %, SD)	264	10.9 (2.8)	129	6.9 (2.4)†
Sedentary time (Mean %, SD)	264	58.8 (57.5)	129	63.4 (5.4)†
Sedentary breaks (frq)	264	253.0 (42.2)	129	263.9 (45.1)
Sedentary bouts (frq)				
2-5 mins	264	37.5 (5.7)	129	42.8 (7.1)†
5-10 mins	264	11.3 (3.0)	129	14.9 (3.3)†
10-15 mins	264	2.7 (1.2)	129	4.1 (1.8)†
≥ 15 mins	264	1.3 (0.8)	129	2.3 (1.5)†
Diet				
Diet composite score#	264	-0.1 (0.9)	129	-0.09 (1.0)
Health measures				
BMI (kg/m^2)	261	17.7 (4.3)	129	19.5 (3.3)†
BMI *z*-score	261	-0.1 (1.0)	129	0.2 (0.8)†
WC (cm)	264	59.0 (6.0)	129	67.8 (9.4)†
SBP (mmHg)	257	102.0 (9.2)	128	112.3 (9.1)†
DBP (mmHg)	257	60.3 (8.1)	128	61.6 (6.2)
TC (mmol/L)[a]	144	4.60 (0.77)		
HDL-C (mmol/L)	144	1.71 (0.33)	113	0.41 (0.28)†
LDL-C (mmol/L)	144	2.54 (0.71)	113	2.58 (0.66)
TG (mmol/L)	144	0.68 (0.25)	113	0.97 (0.45)†
% BF[b]			124	26.0 (6.7)
Clustered CVD risk^	144	-1.5 (2.4)	113	2.0 (3.0)†

Values represent mean (standard deviation, SD) or percentage (%).
Abbreviations: Frq, frequency; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; TG, triglycerides.
Diet energy density composite z-score; ^ Standardised and sum of WC, the average of SBP and DBP, LDL-C, inverted HDL-C and triglycerides.
All rows not equal to 393 due to missing data.
[a] Data available for Transform-Us! only. [b] Data available for LOOK only.
*$p<0.05$, †$p<0.001$

Table 9.23 Percentage of children with elevated levels of CVD risk factors#

CVD Risk factor	Transform-Us! Valid (n)	Transform-Us! %	LOOK Valid (n)	LOOK %
BMI (>25 kg/m^2)	261	22.1	129	24.9*
WC ≥75th percentile	264	19.8	129	35.9†
HDL-C <10th percentile	144	0.8	113	7.1†
LDL-C >90th percentile	144	13.7	113	17.6†
TG ≥90th percentile	144	0.0	113	0.01
DBP and/or SBP >90th percentile	257	19.6	128	22.1*

Determined by age and sex specific cut-points.
*p<0.05, †p<0.001

9.4.2 Associations between total volume of sedentary time, breaks in and bouts of sedentary time and CVD risk factors among 7-12 year olds

Table 9.24 reports the results from the regression analyses of total volume of sedentary time, breaks in and bouts of sedentary time and associations with CVD risk factors and clustered CVD risk score after adjusting for the relevant covariates in models 1 to 4.

Total volume of sedentary time (hours/day) and CVD risk factors

The average number of hours spent sedentary per day was significantly and positively associated with BMI z-score (Model 3, p<0.05) and LDL-C (Model 4, p<0.01) after adjusting for all covariates. After adjusting for sex of the child and accelerometer wear time the total volume of sedentary time was significantly and positively associated with total cholesterol (Model 1, p<0.05). However, the association was attenuated and no longer significant when MVPA, diet and WC were included in the final models (Models 2-4). There were no associations between sedentary time and the remaining lipid and cholesterol markers, blood pressure or CVD risk score.

Frequency of breaks in and bouts of sedentary time and CVD risk factors

The frequency of breaks in and bouts of sedentary time was not associated with any of the CVD risk factors.

Table 9.24 Unstandardised regression coefficients of total volume of sedentary time (hours/day), frequency of breaks in and bouts of sedentary time and CVD risk factors among 7-12 year olds

	Total volume of sedentary time (β, 95% CI)	Sedentary breaks (β, 95% CI)	2-5 minute bouts (β, 95% CI)	5-10 minute bouts (β, 95% CI)	10-15 minute bouts (β, 95% CI)	≥ 15 minute bouts (β, 95% CI)
Adiposity (n=390)						
z-BMI score						
Model 1	-0.09 (-0.23, 0.05)	0.000 (-0.010, 0.051)	-0.01 (-0.03, 0.01)	0.03 (-0.01, 0.07)	0.05 (-0.03, 0.13)	0.05 (-0.05, 0.15)
Model 2	**-0.15 (-0.30, -0.01)***	-0.001 (-0.003, 0.002)	-0.02 (-0.04, 0.00)	0.01 (-0.03, 0.05)	0.02 (-0.05, 0.09)	0.02 (-0.07, 0.12)
Model 3	**-0.15 (-0.29, -0.13)***	-0.001 (-0.003, 0.001)	-0.02 (-0.04 (0.00)	0.01 (-0.03, 0.05)	0.02 (-0.05, 0.09)	0.03 (-0.07, 0.12)
WC (cm)						
Model 1	-0.47 (-1.86, 0.93)	-0.02 (-0.04, 0.01)	-0.12 (-0.32, 0.09)	-0.01 (-0.36, 0.34)	0.27 (-0.49, 1.03)	0.24 (-0.72, 1.20)
Model 2	-1.10 (-2.73, 0.53)	-0.02 (-0.04, 0.01)	-0.16 (-0.36, 0.04)	-0.08 (-0.44, 0.28)	0.23 (-0.54, 0.99)	0.26 (-0.70, 1.22)
Model 3	-1.13 (-2.75, 0.49)	-0.02 (-0.04, 0.01)	-0.16 (-0.36, 0.05)	-0.09 (-0.45, 0.27)	0.22 (-0.55, 0.99)	0.24 (-0.72, 1.20)
Body fat (%)[a]						
Model 1	1.91 (-0.05, 3.86)	-0.01 (-0.04, 0.01)	0.03 (-0.18, 0.24)	0.30 (-0.11, 0.72)	0.19 (-0.45, 0.82)	0.02 (-0.95, 1.00)
Model 2	1.18 (-0.91, 3.27)	-0.01 (-0.03, 0.02)	-0.05 (-0.27, 0.16)	0.14 (-0.25, 0.54)	0.00 (-0.67, 0.68)	-0.16 (-1.09, 0.76)
Model 3	1.51 (-0.41, 3.42)	-0.01 (-0.03, 0.02)	-0.06 (-0.28, 0.17)	0.16 (-0.20, 0.51)	0.05 (-0.73, 0.83)	-0.13 (-1.04, 0.76)
Blood pressure (n=385)						
DBP (mmHg)						
Model 1	0.15 (-1.17, 1.47)	0.00 (-0.03, 0.03)	0.05 (-0.13, 0.22)	0.17 (-0.21, 0.55)	-0.27 (-0.92, 0.38)	0.07 (-0.81, 0.95)
Model 2	-0.34 (-1.68, 1.01)	0.00 (-0.03, 0.03)	0.02 (-0.15, 0.19)	0.12 (-0.28, 0.51)	-0.32 (-1.00, 0.37)	0.08 (-0.80, 0.97)
Model 3	-0.30 (-1.67, 1.07)	0.00 (-0.03, 0.03)	0.01 (-0.16, 0.19)	0.12 (-0.28, 0.52)	-0.31 (-0.97, 0.36)	0.10 (-0.79, 1.00)
Model 4	-0.11 (-1.41, 1.18)	0.00 (-0.02, 0.03)	0.04 (-0.13, 0.21)	0.13 (-0.27, 0.52)	-0.35 (-0.96, 0.26)	0.07 (-0.76, 0.89)
SBP (mmHg)						
Model 1	-0.71 (-2.23, 0.80)	0.00 (-0.04, 0.04)	-0.01 (-0.23, 0.21)	-0.09 (-0.49, 0.31)	-0.24 (-1.28, 0.80)	0.05 (-1.35, 1.46)
Model 2	-1.09 (-2.80, 0.62)	0.00 (-0.04, 0.04)	-0.03 (-0.26, 0.20)	-0.14 (-0.56, 0.28)	-0.28 (-1.33, 0.79)	0.06 (-1.34, 1.47)
Model 3	-1.05 (-2.78, 0.68)	0.00 (-0.04, 0.04)	-0.03 (-0.27, 0.20)	-0.13 (-0.55, 0.29)	-0.26 (-1.31, 0.79)	0.09 (-1.32, 1.49)
Model 4	-0.69 (-2.26, 0.87)	0.00 (-0.04, 0.04)	0.01 (-0.19, 0.22)	-0.12 (-0.54, 0.30)	-0.34 (-1.26, 0.58)	0.02 (-1.25, 1.28)

Table 9.24 continued

	Total volume of sedentary time (β, 95% CI)	Sedentary breaks (β, 95% CI)	2-5 minute bouts (β, 95% CI)	5-10 minute bouts (β, 95% CI)	10-15 minute bouts (β, 95% CI)	≥ 15 minute bouts (β, 95% CI)
Lipids & CVD score (n=257)						
HDL-C (mmol/L)						
Model 1	0.02 (-0.03, 0.08)	0.000 (-0.002, 0.001)	-0.001 (-0.010, 0.007)	0.00 (-0.02, 0.02)	0.02 (-0.03, 0.06)	0.01 (-0.02, 0.04)
Model 2	0.05 (-0.01, 0.11)	0.000 (-0.002, 0.001)	0.000 (-0.009, 0.009)	0.01 (-0.01, 0.03)	0.02 (-0.02, 0.07)	0.01 (-0.02, 0.04)
Model 3	0.05 (-0.01, 0.10)	0.000 (-0.002, 0.001)	0.000 (-0.009,0.009)	0.01 (-0.01, 0.03)	0.02 (-0.02, 0.07)	0.01 (-0.02, 0.04)
Model 4	0.03 (-0.01, 0.08)	-0.001 (-0.002, 0.001)	-0.003 (-0.012, 0.005)	0.01 (-0.01, 0.03)	0.03 (-0.02, 0.07)	0.01 (-0.02, 0.04)
LDL-C (mmol/L)						
Model 1	**0.20 (0.10, 0.31)**[†]	0.001 (-0.001, 0.003)	-0.01 (-0.02, 0.01)	-0.01 (-0.05, 0.04)	-0.04 (-0.13, 0.04)	-0.02 (-0.11, 0.06)
Model 2	**0.19 (0.06, 0.32)****	0.001 (-0.001, 0.003)	-0.01 (-0.03, 0.01)	-0.01 (-0.06, 0.04)	-0.05 (-0.13, 0.04)	-0.02 (-0.11, 0.06)
Model 3	**0.19 (0.07, 0.32)****	0.001 (-0.001, 0.003)	-0.01 (-0.03, 0.01)	-0.01 (-0.06, 0.04)	-0.05 (-0.13, 0.04)	-0.02 (-0.11, 0.07)
Model 4	**0.20 (0.07, 0.32)****	0.001 (-0.001, 0.004)	-0.01 (-0.03, 0.01)	-0.01 (-0.06, 0.04)	-0.05 (-0.13, 0.04)	-0.02 (-0.11, 0.06)
TC (mmol/L)[b]						
Model 1	0.19 (0.00, 0.36)	0.002 (-0.005, 0.008)	-0.02 (-0.05, 0.01)	-0.01 (-0.09, 0.07)	0.04 (-0.17, 0.25)	0.00 (-0.24, 0.24)
Model 2	0.19 (-0.10, 0.48)	0.002 (-0.004, 0.007)	-0.02 (-0.05, 0.01)	-0.01 (-0.09, 0.07)	0.04 (-0.16, 0.24)	0.00 (-0.21, 0.22)
Model 3	0.17 (-0.07, 0.42)	0.002 (-0.004, 0.007)	-0.02 (-0.05, 0.01)	-0.01 (-0.09, 0.07)	0.04 (-0.16, 0.24)	0.00 (-0.22, 0.22)
Model 4	0.18 (-0.07, 0.43)	0.001 (-0.004, 0.007)	-0.02 (-0.05, 0.01)	-0.01 (-0.09, 0.07)	0.04 (-0.16, 0.24)	-0.01 (-0.22, 0.20)
TG (mmol/L)						
Model 1	0.02 (-0.06, 0.10)	-0.001 (-0.002, 0.001)	0.00 (-0.01, 0.01)	0.00 (-0.01, 0.02)	0.00 (-0.04, 0.04)	0.01 (-0.05, 0.07)
Model 2	-0.02 (-0.10, 0.06)	-0.001 (-0.002, 0.001)	-0.01 (-0.02, 0.00)	-0.01 (-0.02, 0.01)	0.00 (-0.05, 0.04)	0.01 (-0.05, 0.07)
Model 3	-0.02 (-0.10, 0.06)	0.000 (-0.002, 0.001)	-0.01 (-0.02, 0.00)	-0.01 (-0.02,0.01)	0.00 (-0.05, 0.04)	0.01 (-0.06, 0.07)
Model 4	0.00 (-0.07, 0.06)	0.000 (-0.002, 0.001)	0.00 (-0.01, 0.01)	-0.01 (-0.02, 0.01)	0.01 (-0.05, 0.03)	0.00 (-0.05, 0.05)
z-CVD score						
Model 1	0.20 (-0.49, 0.88)	-0.001 (-0.013, 0.011)	-0.03 (-0.11, 0.05)	-0.02 (-0.16, 0.13)	-0.10 (-0.47, 0.27)	-0.01 (-0.50, 0.47)
Model 2	-0.08 (-0.78, 0.61)	0.001 (-0.012, 0.012)	-0.06 (-0.14, 0.03)	-0.08 (-0.24, 0.09)	-0.14 (-0.51, 0.23)	-0.01 (-0.50, 0.47)
Model 3	-0.09 (-0.78, 0.60)	0.001 (-0.012, 0.013)	-0.06 (-0.14, 0.03)	-0.08 (-0.24, 0.09)	-0.14 (-0.52, 0.23)	-0.02 (-0.51, 0.47)

All values are unstandardised β, 95% confidence intervals. Model 1 adjusted for school clustering, child age (except z-BMI, TC and %BF), sex of the child and accelerometer wear time; Model 2 additionally adjusted for MVPA (minutes/day); Model 3 additionally adjusted for diet composite score; Model 4 additionally adjusted for waist circumference (where relevant). Abbreviations: Z-BMI, standardised body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; TG, triglycerides. CVD score, clustered CVD risk score determined by the standardized and sum of waist circumference, low density lipoprotein cholesterol, inverted high density lipoprotein cholesterol and triglycerides.

[a] Sample size = 124 (data available from LOOK only), [b] Sample size = 144 (data available from T-Us! only). [#] data rounded to three decimal places due to small values.

* $p<0.05$, ** $p<0.01$, [†] $p<0.001$

9.5 Discussion

The current study examined the associations between the total daily volume of sedentary time, the frequency of breaks in and bouts of sedentary time and CVD risk factors in children aged 7-12 years, independent of key covariates. Few significant and independent associations were evident between total volume of sedentary time and the CVD risk factors examined, except for a positive association with z-BMI and a negative association with LDL-C. There was no association between breaks in and bouts of sedentary time and CVD risk factors.

An unexpected finding from this study was that a higher level of total sedentary time was significantly associated with a lower BMI z-score, after adjusting for all covariates (accelerometer wear time, age, sex of the child, MVPA and diet). That is, for each additional 60 minutes of sedentary time there was a significant reduction in BMI z-score of 0.15. However, the same relation to adiposity was not found with WC which has greater relevance to body composition and is more indicative of other CVD risk factors such as abnormal lipids and raised blood pressure (Daniels et al. 1999).The inverse association with BMI z-score in this chapter contrasts with previous studies that have reported a null association (Carson & Janssen 2011; Chaput et al. 2011; Ekelund et al. 2007; Ekelund et al. 2012; Mitchell et al. 2009; Purslow et al. 2008; Steele et al. 2009; Thompson et al. 2009; Treuth et al. 2005) or a significant positive association (Chinapaw et al. 2012; Colley et al. 2013) between total sedentary time and adiposity.

The contrasting findings noted between the present study and previously published literature could be explained, in part, by methodological differences and accelerometry protocols. For example, only two studies have adjusted for both MVPA and a measure of diet energy density (Carson & Janssen 2011; Cliff et al. 2013). While some studies adjusted for MVPA, the cut-point ranged from 1500cpm (Colley et al. 2013) to 3600cpm (Mitchell et al. 2009) meaning different levels of activity were adjusted for. Among studies that adjusted for a measure of diet quality (Carson & Janssen 2011; Chaput et al. 2011; Cliff et al. 2013), variation in the types of food items recorded and the recall period limits comparability.

Another important consideration is the protocols applied to accelerometer data management across studies. While 20 minutes of consecutive zeroes is widely accepted to reflect non-wear time (Cain et al. 2013), several studies used a lower threshold of 10 minutes (Ekelund et al. 2007; Martinez-Gomez, Eisenmann, et al. 2009; Purslow et al. 2008; Steele et al. 2009), or a higher threshold of 60 minutes (Chaput et al. 2011; Colley et al. 2013; Ekelund et al. 2012) which may over- or under-estimate sedentary time respectively. Additionally, with the exception of one study (Steele et al. 2009), the epoch length used was typically one minute which may mask intermittent bursts of higher intensity activities because counts are summed across the 60 second time frame (Nilsson et al. 2002). Lastly, while the current study utilised the recommended cut-point of ≤100 cpm to define sedentary time (Evenson et al. 2006; Ridgers et al. 2012; Treuth et al. 2004), higher cut-points have been applied (Ekelund et al. 2007; Mitchell et al. 2009), which is likely to overestimate sedentary time and encompass higher intensities of activity that may be associated with health benefits.

The inverse association between sedentary time and BMI z-scores is an unexpected finding that may reflect several of the issues associated with sedentary behaviour research. As seen in Chapter 7 results, time spent in specific SBBs and total screen time did not reflect overall objectively measured sedentary time. Therefore, the beneficial association with z-BMI may reflect children who engage in sedentary behaviours that involve standing with little movement, which has health benefits. As previously discussed the reliance on a cut-point with accelerometer determined sedentary time means it cannot be said with absolute certainty that the individual is sitting. This is an inherent limitation of accelerometers and is a key reason that devices which permit the objective measurement of sitting time should be used (Bassett, Freedson & Kozey 2010). In Chapter 5, it was found that although children engage in high levels of sedentary time it is largely broken up with a high frequency of breaks and accumulated in short bouts. As previously discussed these interruptions to sedentary time may be beneficial to health (see section 2.8). However, there were no other beneficial associations found with the additional CVD risk factors examined in this Chapter.

An important finding in this chapter is the significant and adverse association between the total volume of sedentary time and LDL-C; that is, for every one hour increase in sedentary time there was a 0.20mmHg increase in LDL-C. The strength of the association remained when MVPA, diet energy density and adiposity were included in the models. Conversely, the AFINOS study of adolescents (aged 13-17 years) in Spain reported a null association between sedentary time and LDL-C (Martinez-Gomez, Eisenmann, et al. 2009). However, that study measured sedentary time in one minute epochs, which as previously discussed may mask intermittent burst of higher intensities of activity (Nilson et al. 2002). In addition the non-wear criteria was defined as 10 minutes which may result in an underestimation of sedentary time and MVPA and diet were not controlled for in statistical analysis.

There was a null association between the frequency of breaks in and bouts of sedentary time and CVD risk factors in children in the current study. This finding is consistent with previous studies (Carson & Janssen 2011; Colley et al. 2013). However, Colley and colleagues (Colley et al. 2013) applied non-wear criteria of ≥60 consecutive minutes of zeroes which is likely to inflate true sedentary time by classifying non-wear time as sedentary time. This misclassification could also potentially result in an underestimation of sedentary breaks because there would not be any breaks recorded during these time periods. In addition the longer non-wear time definition, one minute epoch length and forgiveness rule applied may miss transitions to short bursts of light intensity activity and consequently yield a higher frequency of longer bouts. The design and findings of the current study are therefore important because a bout was defined as an isolated period of time that was uninterrupted. The results observed in Chapter 5 show that children's sedentary time is frequently interrupted and is predominantly accumulated in shorter bouts. Given the low frequency of longer sustained bouts in this cohort, children are unlikely to accumulate the sustained sedentary time required to see a health effect.

Strengths and limitations

To the candidate's knowledge this study provides some of the first evidence of patterns of accumulation of sedentary time and associations with CVD risk factors in Australian boys and girls. A key strength was the use of an objective measure for assessing sedentary patterns in combination with standardised measures of CVD risk factors. However, there are limitations of the current study that should be noted. The cross-sectional design limits inferences of causality and its direction. As required by ethics, parents were able to decide which assessment components their child could take part in and this resulted in a smaller sample of children with data available for the blood parameters. However, there were no differences in other health outcomes (adiposity and blood pressure) between children who provided a blood sample and non-responders ($p>0.1$). Lastly, the results may not be generalisable to other population groups such as different age groups.

Conclusion

The study of children's sedentary patterns and CVD health is a new domain of research. In order to inform the development of interventions designed at reducing children's engagement in sedentary time, it is important to understand how such patterns of sedentary time accumulation (total volume, breaks and bouts) are associated with CVD risk factors. While accelerometers provide an objective measure of children's sedentary time, the reliance on cut-points to define sedentary means light-intensity activities and a break in or bout of sedentary time may be misclassified. Moreover, identifying bouts of sedentary time using accelerometers is based on lack of movement, which may due to children sitting or standing for prolonged periods. As such, an important progressive step is to obtain greater measurement accuracy of sedentary behaviour using devices that directly measure posture and postural transitions such as the *activ*PAL^{TM} inclinometer.

Chapter 10
The association between objectively measured patterns of sitting time and cardiovascular risk factors

10.1 Introduction

As described in the literature review (Chapter 2), the current available evidence concerning children's sedentary behaviour and CVD risk factors is derived from measures of screen time (e.g. Rey-Lopez et al. 2008) and more recently hip-mounted accelerometers (e.g. Carson & Janssen 2014; Ekelund et al. 2012; Colley et al. 2013). However, reported (self- or proxy) time spent in different SBBs is subject to recall bias (Loprinzi & Cardinal 2011) and accelerometer determined sedentary time relies on a pre-determined cut-point to estimate a lack of movement (Kozey-Keadle et al. 2011).

Inclinometers provide a direct measure of sitting and postural transitions from sitting or lying down to standing and moving (Bassett, Freedson & Kozey 2010). Specifically, the measurement of posture (the orientation of the thigh) improves measurement accuracy of sitting because there is no reliance on cut-points (Kozey-Keadle et al. 2011), thus it is possible to determine whether someone is sitting or standing. This is particularly important given the unique and beneficial physiological effects associated with standing compared to sitting (Hamilton, Hamilton & Zderic 2007; Hamilton et al. 2008).

The importance of considering how sedentary time is accumulated is reflected in The Australian Physical Activity and Sedentary Behaviour Guidelines for 5-12 year olds which for the first time include a recommendation to break up prolonged periods of sitting time (Department of Health 2014). Although Chapter 9 examined the association between breaks in and bouts of sedentary time and CVD risk factors, the measurement of these patterns is defined by a pre-determined cut-point. Arguably monitors that assess posture (e.g. the *activ*PAL™) can provide greater measurement accuracy of breaks in and bouts of sedentary time because a change in thigh orientation (i.e. the transition from a seated to standing posture) determines a break in or the end of a bout of sitting time.

An important developmental step is to examine sitting time using precise measures of posture such as the *activ*PAL™. Furthermore, given the independent importance of physical activity (McMurray & Ondrak 2013), diet (Getz & Reardon 2007 and adiposity (Bell et al. 2007; Freedman et al. 2007) to CVD health it is important to control for these influences. To the candidate's knowledge, this is the first study to examine the association between patterns of sitting time and CVD risk factors in children using the *activ*PAL™ and adjusting for key confounders.

10.2 Aim

The aim of this chapter is to examine the cross-sectional associations between the average total daily sitting time, patterns of sitting time (sit-to-stand transitions and bouts) assessed using the *activ*PAL™ inclinometer and CVD risk factors in 7-10 year old Australian children.

10.3 Methods

10.3.1 Procedures

Data were drawn from a subsample of Year 3 children from the Transform-Us! study who wore an *activ*PAL™ inclinometer (n=209) during the baseline data collection. The data collection procedures are described in detail in Chapter 3 (see section 3.7.2) and summarised below. Children were fitted with the *activ*PAL™ inclinometer on the anterior aspect of the mid-thigh with an adjustable elastic belt fixed with Velcro™ by trained research staff. Participants were asked to wear the *activ*PAL™ during all waking hours and to remove it during water-based activities such as swimming and bathing, as well as contact sports if needed.

Parents completed a questionnaire which obtained information on family demographics (Appendix C.4), including the parent's age, highest level of education, country of birth, employment and marital status. Parents also reported the child's usual weekly frequency (during the previous month) of their child's consumption of key energy dense sweet and savoury snack foods, fast foods and sweetened drinks (Appendix C.5). Children's height, weight, waist circumference and blood pressure were measured by trained research staff at the child's school. Children with informed parental consent to additionally participate in the biochemical analysis component attended a local pathology clinic to provide a fasted morning blood sample (n=102).

10.3.2 Data management

Inclinometer data reduction

The management of inclinometer data is described in detail in section 3.8.1. Briefly, inclinometer data were downloaded into 15-second epochs using PAL Technologies Professional Version 6.1.2 software. The accelerometer protocols (described in Chapter 5 and 9) were applied to the management of the *activ*PAL™ data. Non-wear time was defined as 20 minutes or more of consecutive zero's (Cain et al. 2013) as measured by the accelerometer function of the *activ*PAL™. Wear time was calculated by subtracting non-wear time from the total waking day (i.e. 6am-10pm). A valid weekday and weekend day was considered to be ≥480 minutes and ≥420 minutes or more of wear time, respectively. Participants were required to have at least three valid weekdays or one valid weekend day to be included in the whole day analyses(Mattocks et al. 2008). For the analysis of discrete periods of the day a criterion of 50% valid period wear time was applied (Hnatiuk et al. 2012; Ridgers et al. 2011).

Sitting time variables

The raw files were processed with a customised Excel Macro to generate time spent sitting, breaks in sitting time and bouts of sitting time within a whole day and specific periods of the day (see section 3.8.1). Bouts that lasted 2-5, 5-10, 10-15 and ≥15 minutes were examined. The first complete 15-second epoch in which sitting was the identified posture defined the beginning of a sitting bout and the bout ended when the child transitioned to an upright posture. Sit-to-stand transitions were used to identify a break in sitting time and was defined as the transition from sitting/lying to standing or stepping that lasted at least one 15-second epoch.

Cardiovascular health measures

The data management procedures and definitions of risk for the anthropometric measures (height, weight and waist circumference), blood pressure (DBP and SBP) and blood lipids (TC, HDL-C, LDL-C, TG) are described in Chapter 3 (section 3.8.4). In order to examine associations between the sitting time/patterns variables and CVD risk factors, only children with complete data within each cardiovascular health outcome were included.

Clustered CVD risk score

As described in section 3.8.4, a continuously distributed clustered CVD risk score was derived by standardising and summing WC, the average of SBP and DBP, LDL-C, inverted HDL-C and triglycerides. A complete set of each of these CVD risk factors was required to be included in the analysis of clustered CVD risk (i.e. WC, SBP, DBP, HDL-C, LDL-C & TG).

Diet energy density

The data collection procedures for the parent proxy-report of children's individual food and beverage consumption items (Appendix C.5) are described in section 3.7.5. Parents reported the child's usual consumption of key energy dense foods (salty snacks, chocolate and sweets, cakes, pastries, fast food, chips) on a nine point scale, and beverages (fruit juice and soft drinks) on an eight point scale. As described in section 3.8.3, a diet energy density score was created using the sum of the scores.

10.3.3 Data analyses

All analyses were undertaken with Stata/SE version 12 (StataCorp 2011). The distribution of each of the outcome variables were assessed for normality. BMI was positively skewed, therefore age and sex adjusted BMI z-scores (Cole et al. 2000) were calculated and used in all analyses.

Forced entry linear regression models were used to examine the associations between weekly weighted sitting time (hours/day), frequency of breaks in sitting time, frequency of bouts of sitting time, and CVD risk factors and clustered CVD risk. On account of the small sample size bootstrapping was used to randomly sample with replacements. Bootstrapping (2000 resamples) was used to produce robust estimates of standard errors and 95% confidence intervals (Fox 2008).

Consistent with Chapter 9, the following covariates were included: child sex, *activ*PAL^{TM} wear time, *activ*PAL^{TM} determined stepping time (minutes/day), and diet energy density composite score. Four statistical models were used to examine the association between the independent variables and CVD health outcomes; Model 1 adjusted for school clustering, sex of the child (except for the outcome BMI z-score) and *activ*PAL^{TM} wear time; Model 2 additionally adjusted for *activ*PAL^{TM} determined stepping time (minutes/day); Model 3 additionally adjusted for diet energy density composite score; and where adiposity was not the outcome of interest Model 4 additionally adjusted for waist circumference.

10.4 Results

10.4.1 Characteristics of the study participants

The characteristics of the children from the Transform-Us! subsample who had activPAL^{TM} data are described in Table 10.25. Just over half (53%) of the participants were female and the mean age was 8.2 (0.4) years. Close to half of parents had a university degree (46.7%). Children wore the *activ*PAL^{TM} on average for 668.7 (52.6) minutes per day and of this time approximately 110 minutes was spent in stepping time and just over 60% of wear time was spent sitting.

As described in Table 10.26, over a quarter of children were classified as overweight or obese as measured by BMI (27.1%) and WC (30.6%). Approximately 20% of participants had SBP or DBP above the 90th percentile. No participants had HDL-C below the 10th percentile or TG above the 90th percentile; however, approximately 10% of participants had LDL-C levels above the 90th percentile. There were no significant differences in the non-blood health measures between children who provided a blood sample and children who did not provide a blood sample (p>0.1).

Table 10.25 Participant characteristics

Measures	n	Mean (SD)
Age	108	8.2 (0.4)
Parent education (% university)	107	46.7
***activ*PAL™ variables**		
Wear time (mins/day)	107	668.7 (52.6)
Stepping time (mins/day)	107	110.6 (27.8)
Sitting time (Mean %, SD)	107	62.4 (9.4)
Sit-to-stand transitions (frq)	107	88.1 (20.1)
2-5 minute bouts (frq)	107	17.2 (4.3)
5-10 minute bouts (frq)	107	11.2 (2.7)
10-15 minute bouts (frq)	107	5.0 (1.4)
≥15 minute bouts (frq)	107	6.1 (1.9)
Diet		
Diet composite score[#]	107	21.3 (4.9)
Health measures		
BMI (kg/m^2)	107	17.3 (2.2)
BMI *z*-score	107	0.38 (0.85)
WC (cm)	107	59.0 (5.4)
SBP (mmHg)	105	101.4 (9.5)
DBP (mmHg)	105	59.8 (9.1)
TC (mmol/L)	73	4.48 (0.73)
HDL-C (mmol/L)	73	1.71 (0.33)
LDL-C (mmol/L)	73	2.45 (0.67)
TG (mmol/L)	73	0.67 (0.25)
Clustered CVD risk^	73	-0.78 (2.36)

Values represent mean (standard deviation, SD) or percentage (%). Frq. denotes frequency.

Significant differences indicated in bold; * $p<0.05$ boys versus girls.

Abbreviations: WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; TG, triglycerides.

[#] Weekly weighted average

^ Standardised and sum of WC, SBP, DBP, LDL-C, inverted HDL-C and TG.

Table 10.26 Percentage of children with elevated levels of CVD risk factors

CVD Risk factor	Valid (n)	%
BMI (>25 kg/m2)	107	27.1
WC ≥75th percentile	107	30.6
HDL-C <10th percentile	73	0
LDL-C >90th percentile	73	10.9
TG ≥ 90th percentile	73	0
DBP or SBP >90th percentile	105	20.5

Abbreviations: WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; TG, triglycerides.

10.4.2 Associations between total sitting time, sit-to-stand transitions, bouts of sitting time and CVD risk factors

Table 10.27 describes the results from the linear regression analyses of sitting time, sit-to-stand transitions, bouts of sitting time and associations with CVD risk factors and the clustered CVD risk score, after adjusting for the various covariates in Models 1-4.

Total sitting time and CVD risk factors

Total sitting time per day was significantly and positively associated with DBP after adjusting for school clustering, child sex and monitor wear time (Model 1; $p<0.05$). However, the association was attenuated and no longer significant after adjusting for stepping time, diet energy density, and waist circumference (Models 2-4). There was no association between the children's total sitting time, adiposity, biochemical markers and CVD risk score.

Frequency of sit-to-stand transitions and CVD risk factors

The frequency of sit-to-stand transitions was significantly and beneficially associated with lower SBP, after adjusting for all covariates (Model 4; $p<0.05$). However, there was no association between the frequency of sit-to-stand transitions and adiposity, biochemical markers or CVD risk score in any of the models.

Frequency of bouts of sitting time and CVD risk factors

There were no associations between the frequency of 2-5 minute sitting bouts and CVD risk factors in any of the models. The frequency of 5-10 minute sitting bouts was significantly and beneficially associated with lower SBP after adjusting for all covariates (Model 4; $p<0.05$). However, there was no association between the frequency of 5-10 minute sitting bouts and adiposity, biochemical markers, or CVD risk score in any of the models.

The frequency of 10-15 minute sitting bouts was significantly and adversely associated with triglycerides after adjusting for all covariates (Model 4; $p<0.05$). However, there were no associations between the frequency of 10-15 minute sitting bouts and adiposity, blood pressure, other cholesterol markers or CVD risk score in any of the models. There were no associations between the frequency of sitting bouts ≥15 minutes and CVD risk factors in any of the models.

Table 10.27 Unstandardised regression coefficients (β, 95% CI) of sitting time (hours/day), frequency of sit-to-stand transitions in and bouts of sitting time and CVD risk factors among 7-10 year old children

	Sitting time (β, 95% CI)	Sit-to-stand (β, 95% CI)	2-5 min bouts (β, 95% CI)	5-10 min bouts (β, 95% CI)	10-15 min bouts (β, 95% CI)	≥ 15 min bouts (β, 95% CI)
Adiposity (n=107)						
z-BMI score						
Model 1	0.05 (-0.09, 0.19)	-0.01 (-0.02, 0.00)	-0.02 (-0.07, 0.04)	-0.04 (-0.11, 0.17)	0.00 (-0.15, 0.15)	0.01 (-0.17, 0.18)
Model 2	0.10 (-0.22, 0.41)	-0.01 (-0.02, 0.00)	-0.02 (-0.07, 0.02)	-0.05 (-0.11, 0.01)	-0.01 (-0.16, 0.13)	0.00 (-0.18, 0.19)
Model 3	0.07 (-0.25, 0.38)	-0.01 (-0.02, 0.00)	-0.02 (-0.07, 0.02)	-0.05 (-0.12, 0.01)	-0.01 (-0.15, 0.14)	0.00 (-0.19, 0.19)
WC (cm)						
Model 1	-0.11 (-0.72, 0.49)	-0.02 (-0.10, 0.05)	-0.04 (-0.34, 0.26)	-0.15 (-0.55, 0.24)	0.17 (-0.56, 0.91)	-0.06 (-1.25, 1.23)
Model 2	0.02 (-1.62, 1.66)	-0.03 (-0.11, 0.05)	-0.05 (-0.35, 0.25)	-0.17 (-0.59, 0.24)	0.16 (-0.60, 0.92)	-0.08 (-1.31, 1.15)
Model 3	-0.13 (-1.76, 1.49)	-0.03 (-0.11, 0.05)	-0.06 (-0.37, 0.26)	-0.19 (-0.61, 0.23)	0.19 (-0.59, 0.97)	-0.10 (-1.36, 1.16)
Blood pressure (n=105)						
DBP (mm Hg)						
Model 1	0.86 (-0.05, 1.78)	-0.01 (-0.07, 0.06)	0.02 (-0.21, 0.25)	-0.38 (-0.84, 0.09)	-0.54 (-1.35, 0.26)	1.14 (-0.25, 2.53)
Model 2	1.14 (-0.95, 3.23)	-0.01 (-0.08, 0.06)	0.00 (-0.25, 0.26)	-0.41 (-0.91, 0.09)	-0.70 (-1.77, 0.39)	1.13 (-0.28, 2.54)
Model 3	1.03 (-0.95, 3.01)	-0.01 (-0.08, 0.06)	0.00 (-0.26, 0.26)	-0.43 (-0.95, 0.10)	-0.68 (-1.75, 0.39)	1.12 (-0.30, 2.53)
Model 4	1.04 (-0.84, 2.92)	-0.01 (-0.06, 0.05)	0.02 (-0.21, 0.26)	-0.39 (-0.89, 0.11)	-0.74 (-1.83, 0.35)	1.15 (-0.21, 2.51)
SBP (mm Hg)						
Model 1	0.86 (-0.75, 2.46)	**-0.10 (-0.18, -0.02)***	-0.20 (-0.55, 0.15)	**-0.61 (-1.16, -0.07)***	-1.16 (-2.38, 0.05)	0.47 (-1.13, 2.07)
Model 2	0.72 (-1.91, 3.37)	**-0.11 (-0.18, -0.03)****	-0.21 (-0.56, 0.15)	**-0.63 (-1.14, -0.12)***	-1.30 (-2.61, 0.00)	0.49 (-1.09, 2.08)
Model 3	0.45 (-2.06, 2.95)	**-0.11 (-0.19, -0.03)****	-0.22 (-0.56, 0.13)	**-0.66 (-1.24, -0.09)***	-1.26 (-2.62, 0.09)	0.46 (-1.15, 2.06)
Model 4	0.45 (-2.04, 2.95)	**-0.10 (-0.18, -0.02)***	-0.19 (-0.55, 0.16)	**-0.62 (-1.19, -0.05)***	**-1.33 (-2.65, -0.02)***	0.50 (-0.99, 1.98)

Table 10.27 continued

	Sitting time (β, 95% CI)	Sit-to-stand (β, 95% CI)	2-5 min bouts (β, 95% CI)	5-10 min bouts (β, 95% CI)	10-15 min bouts (β, 95% CI)	≥ 15 min bouts (β, 95% CI)
Cholesterol and lipids (n=73)						
HDL-C (mmol/L)						
Model 1	0.02 (-0.04, 0.08)	0.00 (-0.01, 0.00)	0.00 (-0.03, 0.02)	0.00 (-0.03, 0.04)	-0.02 (-0.08, 0.04)	0.07 (-0.01, 0.15)
Model 2	-0.01 (-0.12, 0.11)	0.00 (-0.01, 0.00)	0.00 (-0.03, 0.02)	0.00 (-0.03, 0.04)	-0.01 (-0.08, 0.06)	0.07 (-0.02, 0.15)
Model 3	0.01 (-0.10, 0.11)	0.00 (-0.01, 0.01)	0.00 (-0.03, 0.03)	0.01 (-0.03, 0.04)	-0.02 (-0.08, 0.05)	0.06 (-0.02, 0.12)
Model 4	0.00 (-0.09, 0.08)	0.00 (-0.01, 0.00)	0.00 (-0.03, 0.02)	0.01 (-0.02, 0.04)	0.00 (-0.06, 0.06)	0.05 (-0.02, 0.12)
LDL-C (mmol/L)						
Model 1	-0.10 (-0.22, 0.02)	0.00 (-0.01, 0.01)	0.01 (-0.04, 0.05)	0.03 (-0.06, 0.11)	0.01 (-0.18, 0.20)	-0.03 (-0.18, 0.13)
Model 2	-0.20 (-0.45, 0.04)	0.00 (-0.01, 0.01)	0.01 (-0.04, 0.06)	0.03 (-0.05, 0.11)	0.03 (-0.19, 0.25)	-0.02 (-0.18, 0.14)
Model 3	-0.21 (-0.48, 0.05)	0.00 (-0.01, 0.01)	0.01 (-0.04, 0.06)	0.03 (-0.05, 0.11)	0.04 (-0.18, 0.25)	-0.02 (-0.18, 0.14)
Model 4	-0.20 (-0.48, 0.07)	0.00 (-0.01, 0.01)	0.01 (-0.04, 0.07)	0.03 (-0.06, 0.11)	0.02 (-0.19, 0.23)	0.00 (-0.17, 0.17)
TC (mmol/L)						
Model 1	-0.08 (-0.20, 0.04)	0.00 (-0.01, 0.01)	0.00 (-0.06, 0.05)	0.04 (-0.06, 0.14)	0.01 (-0.17, 0.18)	0.06 (-0.10, 0.22)
Model 2	-0.23 (-0.46, 0.00)	0.00 (-0.01, 0.01)	0.01 (-0.05, 0.06)	0.04 (-0.05, 0.14)	0.04 (-0.16, 0.23)	0.07 (-0.10, 0.24)
Model 3	-0.22 (-0.47, 0.04)	0.00 (-0.01, 0.01)	0.01 (-0.05, 0.07)	0.04 (-0.05, 0.14)	0.03 (-0.16, 0.23)	0.07 (-0.11, 0.25)
Model 4	-0.22 (-0.48, 0.05)	0.00 (-0.01, 0.01)	0.01 (-0.05, 0.07)	0.04 (-0.05, 0.14)	0.03 (-0.16, 0.23)	0.07 (-0.11, 0.25)
Triglycerides (mmol/L)						
Model 1	0.00 (-0.03, 0.03)	0.00 (-0.004, 0.004)[#]	0.00 (-0.02, 0.01)	0.02 (-0.01, 0.04)	0.05 (0.00, 0.11)	0.02 (-0.05, 0.08)
Model 2	-0.05, (-0.13, 0.03)	0.00 (-0.003, 0.005)	0.00 (-0.01, 0.02)	0.02 (-0.01, 0.05)	**0.07 (0.02, 0.11)****	0.02 (-0.05, 0.09)
Model 3	-0.05 (-0.14, 0.04)	0.00 (-0.003, 0.005)	0.00 (-0.01, 0.02)	0.02 (-0.01, 0.05)	**0.06 (0.01, 0.12)***	0.02 (-0.05, 0.09)
Model 4	-0.04 (-0.13, 0.04)	0.00 (-0.003, 0.005)	0.00 (-0.01, 0.02)	0.02 (-0.01, 0.05)	**0.06 (0.00, 0.12)***	0.03 (-0.04, 0.09)

Table 10.27 continued

	Total sitting time (hrs/day) (β, 95% CI)	Sitting breaks (β, 95% CI)	2-5 minute bouts (β, 95% CI)	5-10 minute bouts (β, 95% CI)	10-15 minute bouts (β, 95% CI)	≥ 15 minute bouts (β, 95% CI)
CVD score (n=73)						
Model 1	-0.14 (-0.61, 0.31)	0.01 (-0.03, 0.04)	-0.01 (-0.20, 0.19)	0.07 (-0.19, 0.32)	0.26 (-0.19, 0.72)	-0.27 (-1.08, 0.54)
Model 2	-0.51 (-1.44, 0.40)	0.01, (-0.05, 0.06)	0.01 (-0.20, 0.22)	0.08 (-0.18, 0.33)	0.36 (-0.20, 0.91)	-0.25 (-1.07, 0.57)
Model 3	-0.54 (-1.49, 0.40)	0.01 (-0.05, 0.06)	0.01 (-0.20, 0.21)	0.07 (-0.18, 0.33)	0.37 (-0.17, 0.92)	-0.24 (-1.07, 0.59)

All values are unstandardised β, 95% confidence intervals. Model 1 adjusted for school clustering, sex of the child, sitting time (where sitting time was not the dependent variable) and *activ*PAL™ wear time; Model 2 additionally adjusted for *activ*PAL™ stepping time (minutes/day); Model 3 additionally adjusted for diet composite score; Model 4 additionally adjusted for waist circumference.

Abbreviations: HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; TG, triglycerides; WC, waist circumference; CVD score, clustered CVD risk score determined by standardizing and summing WC, SBP, DBP, LDL-C, inverted HDL-C and TG.

[#] Data presented to three decimal places due to small values.

* p <0.05, ** p <0.01

10.5 Discussion

The current study described the association between total sitting time, the frequency of sit-to-stand transitions and bouts of sitting time and CVD risk factors in 7-10 year old Australian children. The main finding was that total volume of sitting time, assessed with the *activ*PAL^{TM}, was not associated with any of the CVD risk factors; however, some associations were observed with sit-to-stand transitions and bouts of sitting time.

A higher frequency of sit-to-stand transitions and bouts of 5-10 and 10-15 minutes of sitting time were beneficially associated with lower SBP. Interestingly, there was not a significant association between bouts that lasted longer than 15 minutes SBP either adversely or beneficially. This finding suggests there may be a point at which the length of a sedentary bout has different implications for CVD risk factors. The results observed in Chapter 6 show that children's sitting time is frequently interrupted, particularly on weekdays, and is predominantly accumulated in shorter bouts. Given the low frequency of bouts lasting longer than 15 minutes in this cohort, it is possible that children did not accumulate the sustained sitting required to see a health effect. It is also a consideration with the measurement of the frequency of sitting bouts longer than 15 minutes that a lower frequency may reflect longer sitting duration and a high frequency a lower sitting duration. Further assessment of bouts using different sampling frames, including average duration and minutes will be important in determining the health effects of sustained sitting.

In contrast to the beneficial negative association between 10-15 minute bouts and SBP levels, triglyceride levels were adversely associated with this bout length. However, the association was not significant with bouts longer than 15 minutes. As with SBP it may be that the low frequency of bouts lasting longer than 15 minutes in this cohort means children are unlikely to accumulate the sustained sitting required to see a health effect. The evidence of adverse and beneficial associations with CVD risk factors highlights the complexities of determining the threshold at which sustained bouts of sedentary time are biologically meaningful as the effect on CVD risk factors may differ. Experimental studies may therefore be needed to determine dose-response relationships.

No significant associations were found between the total volume of sitting time and any of the CVD risk factors examined. Several factors may contribute to this finding. Firstly, although physical activity was adjusted for, the variable used was stepping time rather than MVPA. Stepping time encompasses stepping of any intensity (light and above), which may have resulted in an over-adjustment for physical activity. In addition, MVPA is beneficially associated with cardiovascular health (McMurray & Ondrak 2013) and may be an important behavioural mediator that was not specifically adjusted for. Furthermore, as discussed in Chapter 7 results, the significant and positive association between TV viewing and sitting time on weekends in girls requires further investigation with a larger sample size using direct measures of posture. If total sitting time is indicative of girls who spend the most time sitting, snacking while watching TV, rather than overall diet quality, may be an important behavioural mediator for consideration in future studies.

Strengths and limitations

To the candidate's knowledge, this study provides the first evidence of patterns of sitting time accumulation and associations with CVD risk factors in a sample of Australian children. A key strength of the current study is the direct measure of posture to objectively assess time spent in a sitting position, sit-to-stand transitions and bouts of sitting time in combination with objective and standardised measures of CVD risk factors. However, there are limitations of the current study that should be noted. Firstly, due to the secondary nature of the analyses, this study was not powered *a priori*. While bootstrap techniques were used to address the accuracy of the inference given a small sample size, it is a consideration that the sample size may still have contributed to the null associations. Secondly, stepping time from the inclinometer, rather than accelerometer determined MVPA was used. The cross-sectional design limits inferences of causality and its direction. In addition, children were able to decide which assessment components they took part in and this resulted in a smaller sample of children with data available for the blood parameters. However, there was no difference in the other health outcomes (adiposity and blood pressure) between children who provided a blood sample and non-responders ($p>0.1$). Lastly, the results may not be generalisable to other population groups such as different age groups.

Conclusion

The current study is the first to explore associations between objectively-assessed patterns of sitting time and CVD risk factors in children. Though few health associations were observed, it is important to consider that the sample comprised of primary school children who have had limited life time exposure to sedentary behaviours. Given the infancy of such research, the results provide an initial insight into the potential effects of sitting time accumulation on health and a foundation for future research to build on. This includes assessing larger cohorts of children, further exploration of the thresholds of bouts that are biologically meaningful, and utilisation of CVD health measures that have greater sensitivity and specificity which may detect physiological changes even in apparently healthy individuals. The significantly positive association between sit-to-stand transitions, bouts of sitting time and some CVD risk factors suggests that in this age group the transition from sitting to upright may be a particularly important target for future research and interventions.

Chapter 11
Conclusion

11.1 Overview of findings

This thesis makes an important contribution to the evidence base concerning primary school children's total and accumulated sedentary behaviour and associations with CVD risk factors. Three different measures were used to examine sedentary behaviour (proxy-reported time spent in different SBBs) and sedentary and sitting time (hip mounted accelerometers and thigh mounted inclinometers respectively). The relevance of utilising these measures is reflected in Australia's Physical Activity and Sedentary Behaviour Guidelines, (The Department of Health 2014) which comprises both a recommendation for limiting screen time and one for reducing and breaking up sitting time, thereby requiring an objective measure of postural allocation. In addition, the updated definition of sedentary behaviour (SBRN 2012) reflects the value in utilising different types of measures of sedentary behaviour, with a component that addresses energy expenditure (≤ 1.5 METs) and postural allocation (sitting). In this thesis, these measures were utilised to describe the context of children's sedentary behaviour as well as total sedentary and sitting time and patterns of sedentary and sitting time accumulation across discrete periods of the weekday and weekend day.

The findings from the investigation of the prevalence and patterns of children's sedentary time, discussed in Chapters 4 to 6, indicate that children are engaging in high levels of sedentary time irrespective of the method used to measure sedentary behaviour. Population surveillance data (Active Healthy Kids Canada

2014; ABS 2013b; Sisson 2009) has reported that between 40 and 80% of young people are spending more than two hours a day in electronic media. Similarly, 60% of children from Transform-Us! exceeded screen time recommendations and this was higher on weekend days compared to weekdays (Chapter 4). This suggests that strategies to limit children's screen time should target weekends in particular. TV viewing accounted for the highest percentage of total screen time compared to the other SBBs, although boys engaged in a higher percentage of time in e-games compared to girls and this was particularly evident on weekend days.

When sedentary and sitting time prevalence and patterns were measured objectively, approximately six hours (60%) of the waking day was spent sedentary or sitting. Previous studies have reported comparable daily estimates using inclinometers (Hinckson et al. 2013) and accelerometers in population studies (Matthews et al. 2008; Nilsson et al. 2009; Steele et al. 2010) in children. However, few studies have assessed temporal patterns of total sedentary time within discrete periods of the day (Bailey et al. 2012; Steele et al. 2010), and to the best of the candidate's knowledge there are no studies which have assessed breaks and bouts within periods of the day. The findings discussed in Chapters 5 and 6 shows there was a clear and distinct pattern of peaks in sedentary and sitting time occurring during class periods and after school yet little variability in the percentage of sedentary/sitting time across all periods of the weekend day. Therefore, while the structure of the school day may promote sedentary time during class periods, the lack of structure during a weekend day may equally facilitate sedentary behaviour. Lastly, while children engage in high levels of sedentary and sitting time, the accumulation of that time was predominantly in shorter bouts with a high frequency of breaks, suggesting children's sedentary behaviour is intermittent. Encouraging and supporting children from a young age to frequently interrupt their sitting time may establish good habits early in life that are carried through into adolescence and adulthood.

This thesis also examined whether proxy-reported time spent in specific SBBs and total screen time are indicators of sedentary and sitting time (overall and in sustained bouts). If screen time reflects overall sedentary/sitting time or the accumulation of sedentary/sitting time, such as fewer breaks and longer uninterrupted bouts, simple behavioural questions may be useful in identifying children at risk of a sedentary lifestyle. This is important to ascertain as it may alleviate the need for the use of field based accelerometers or inclinometers which can have prohibitively high costs and greater participant burden. Previous studies have reported a positive (Kiltsie et al. 2013) and a null association (Verloigne et al. 2013) between sedentary time and screen time. However, these studies did not assess the association with breaks and bouts of sedentary time and to the candidate's knowledge there is no evidence to date of the association between different SBBs or total screen time and objectively measured sitting time, sit-to-stand transitions or bouts of sitting time using the *activ*PAL™.

The main finding from Chapter 7 was that time spent in different SBBS was not a good indicator of sedentary time or patterns of sedentary time. This is important given the dominance of measures of total screen time and TV viewing in the literature (Tremblay et al. 2011). The exception was that time spent in e-games on weekend days was associated with a higher level of sedentary time. In addition, when associations were assessed between different SBBS and sitting time and patterns of sitting time, it was found that TV viewing time was an indicator of girls' total sitting time and a higher frequency of longer bouts of sitting time on weekend days.

Lastly, this thesis utilised the various sedentary measures described above and examined associations with CVD risk factors in children (adiposity, blood pressure and lipids). Previous studies of objectively measured sedentary behaviour and CVD health in children have rarely controlled for MVPA and diet energy density despite the relation of these lifestyle factors to CVD risk (Getz & Reardon 2007; McMurray & Ondrak 2013). Of studies that have examined the associations between sedentary behaviour and CVD risk factors (Froberg & Raustorp 2014), few controlled for both MVPA and diet (Carson & Janssen 2011; Cliff et al. 2013). These studies also assessed sedentary patterns and CVD risk factors; however, the results are limited to US youth (Carson & Janssen 2011) and obese children (Cliff et al. 2013) and only accelerometers were used to measure sedentary behaviour.

As described in Chapters 8 to 10, while time spent in different SBBs had some differential associations with CVD risk factors, this was predominantly limited to TV viewing which was adversely associated with adiposity and SBP. Total time spent sedentary and sitting were not associated with any of the CVD biomarkers. However, the findings from the examination of sit-to-stand transitions and bouts showed an interesting relation to CVD risk factors with a beneficial association between a higher frequency of breaks and shorter bouts in sitting time with SBP and 10-15 minute sedentary bouts with HDL-C. The findings from each of the three sedentary measures resulted in different associations with CVD risk factors which suggests these sedentary measures are capturing different aspects of sedentary behaviour. The strengths and limitations of these measures and also of the thesis studies generally are explored in the following section.

11.2 Strengths and limitations

An important strength of this thesis is the use of three key measures of sedentary behaviour that each provides highly relevant and unique information within sedentary behaviour research. To date, screen time has been the dominant measure used to assess children's sedentary behaviour due to the ease of administration and cost-effectiveness of questionnaires (Trost 2007). Reported time spent in TV viewing, e-games and computer use provides important information about specific behavioural targets. However, to date many studies have not distinguished between different screen-behaviours which may inform the development of future interventions. This was addressed in Chapter 4 which examined different types of SBBs separately and in combination as a measure of total screen time.

The second measure of sedentary behaviour used in this thesis was the ActiGraph which provides objective date and time stamped information and has therefore increased in use in recent years in sedentary behaviour research (Cain et al. 2013). The ActiGraph model used in this thesis (GT3X) is the most commonly used accelerometer (Reilly 2008) and has acceptable cross-model reliability when compared with earlier models produced by the same manufacturer (Robusto 2012). The customised Excel Macro enabled discrete time periods of the weekday and weekend day to be examined as well as specific bout lengths and breaks in sedentary time. It is unlikely that this type of behavioural information could be captured by self- or proxy-report. Therefore, key periods in which sedentary/sitting time was high and the frequency of breaks and bouts within those periods was identified, which has important implications for public health strategies that aim to reduce overall and uninterrupted periods of sedentary behaviour.

A consideration, however, is the Excel Macro was designed to examine periods of the day that matched a school day (e.g. class time, break time and before and after school). These same periods were examined on weekend days which do not have the same structure as a school day and it is unlikely that children's behaviour on a weekend day mirrors that of a school day. With the exception of time use diaries it is difficult to ascertain discrete weekend day periods due to the high levels of discretionary time and wide variability from one person to another as to patterns of behaviour. Therefore, these time periods were chosen to enable comparability across days of the week. Lastly, an inherent limitation of accelerometers is the reliance on a pre-determined cut-point to define sedentary time. The widely accepted cut-point of <100 cpm (Ridgers et al. 2012) was used and therefore the results have greater comparability with other studies of accelerometer determined sedentary time. However, an important aspect of the SBRN (2012) definition of sedentary behaviour is the specification of sitting, and counts below an arbitrary threshold may include standing with little movement in addition to time spent sitting.

The final sedentary behaviour measure used was the *activ*PAL^{TM}. The use of devices which permit the objective measurement of sitting time has been encouraged in sedentary behaviour research (Bassett, Freedson & Kozey 2010). Therefore, a key strength of this thesis is the use of the *activ*PAL™ inclinometer which measures the inclination of the thigh and therefore whether a person is sitting or standing (Kozey-Keadle et al. 2011). As with the ActiGraph data, the customised Excel Macro enabled discrete periods of the week day and weekend day to be examined as well as sit-to-stand transitions and different bouts lengths of sitting time on weekdays and weekend days. The identification of periods of high levels of sitting time has important implications for public health strategies that aim to reduce overall and uninterrupted periods of sedentary behaviour. Although, as with the interpretation of the ActiGraph temporal patterns, it is a consideration that weekend day periods were matched to weekday periods.

The adjustment for key confounders in this thesis is an important strength. Many previous studies have failed to adjust for MVPA, a measure of diet quality or adiposity (when not the outcome). Evidence of the association between sedentary behaviour and CVD risk factors is inconclusive in children (Froberg &Raustorp 2014) and the variation between studies in the adjustment for MVPA, diet and adiposity is likely to be a contributing factor. Furthermore, studies that have failed to adjust for these confounding factors have not assessed the independent association between sedentary behaviour and CVD health indicators.

The generalisability of the findings presented in this thesis is limited to families who are predominantly Caucasian and of low to mid socio-economic status. In Transform-Us!, low, mid and high SES schools were invited to participate yet only one school classified as high SES agreed to participate. In the LOOK study the recruitment strategy was designed to recruit households in which the average household income was similar to the mean for Australian city dwellers. In both the Transform-Us! and LOOK cohorts participants may represent children who are healthier and less sedentary compared to the general population. However, the prevalence of overweight and obesity and the percentage of children who exceeded screen time guidelines was similar to national averages (ABS 2013a).

An important consideration in the interpretation of findings presented in this thesis is the cross-sectional design and therefore the inability to determine causality (e.g. whether sedentary behaviour resulted in higher levels of overweight or if children who were overweight were more likely to be sedentary). As cross-sectional studies are needed to generate hypotheses for further research, the findings presented on sedentary behaviour and CVD health provides important initial evidence upon which to inform future studies. Finally, as data were collected at one time point seasonality is an unavoidable consideration. In both Transform-Us! and LOOK, data were collected in the warmer months. Sedentary time may therefore differ in comparison to other seasons, although evidence of variations in sedentary behaviour levels according to seasons is inconclusive (Rich, Griffiths & Dezateux 2012).

11.3 Implications for future research and interventions

Types of screen-based behaviours to measure

Further research is needed which considers a wider range of screen-based technologies in children. The emergence of new screen-based technologies in recent years, such as e-readers, tablet computers and smart phones, means the nature of screen-based behaviour is changing (Jago et al. 2011). In addition to an increase in options for screen-based pursuits, these new technologies are easily portable making it possible to engage in multiple screen behaviours at any one time (e.g. watching TV while using a tablet computer). Multi-media tasking may make it more difficult for children and parents to recall screen time. This will be an important issue for future research to address so that screen time can be more accurately measured in epidemiological studies and population estimates of compliance with screen time guidelines.

The higher percentage of time spent in e-games among boys in this thesis, which is consistent with previous studies (Gorely et al. 2009; Gorely et al. 2007; Kiltsie et al. 2013; Verloigne et al. 2013), suggests there may be differences in the types of SBBs that boys and girls engage in. Therefore, in addition to assessing the usage of new screen technologies, it will be important for future research to assess differences in their usage between boys and girls. This will have important implications for the development of public health strategies and interventions that aim to reduce children's screen time as maximum effectiveness may require different strategies for boys and girls depending on screen-based preferences. In addition, previously screen time has predominantly been measured within leisure time outside of school hours and on weekends. However, the increasing portability of these devices means they can be used anywhere. Therefore it may be an important for future research to also capture screen time usage during the school day, particularly during break periods.

A further consideration for future research concerns the type of SBBs to assess in relation to the relevance to cardiovascular health. As discussed in Chapter 2 (section 2.1), several reviews have examined the evidence from studies of screen time and CVD risk factors (in particular adiposity), and greater strength of evidence for an association between TV viewing and adiposity, compared to e-games and computer use, has been reported (Rey-Lopez et al. 2008; Tremblay, LeBlanc, Kho, et al. 2011). Similarly, in this thesis, TV viewing was more consistently associated with adiposity compared to e-games and computer use. Future studies of specific SBBs and CVD health may therefore only need to measure TV viewing time. However, limited evidence is available regarding computer use and e-games to a wider range of CVD risk factors, such as blood pressure and adverse lipid profiles and further research, including longitudinal studies, is needed. In addition, given the range of screen-based technologies now available it will be important to determine if these are replacing other more 'traditional' types of screen-based pursuits and determine whether they increase CVD risk factors in children.

Accelerometer and inclinometer determined sitting time, breaks and bouts

Given the popularity of accelerometers for the objective measurement of sedentary behaviour (Reilly et al. 2008), an important consideration is the validity of the inclinometer function to measure sitting time. The inclinometer in the new generation of accelerometers has the same limitation as the previous model in as much as while it is worn at the waist it may be challenging to detect postural allocation. Therefore, a future validation study could compare data from the inclinometer function of the ActiGraph with that of the *activ*PAL.

Furthermore, an important consideration for future research will be to determine how well accelerometer-assessed breaks and bouts reflect actual interruptions in sitting time. The difference in the frequency of breaks and bouts measured with the ActiGraph and the activPAL™ suggests the ActiGraph may over-estimate breaks. While it may also be that the *activ*PAL™ underestimates sit-to-stand transitions, this is unlikely because the *activ*PAL™ directly measures the angle of the thigh and has been validated for the assessment of sit-to-stand transitions (Grant et al. 2006; Lyden et al. 2012). Equally, the frequency of bouts differed in this thesis, with a higher frequency of shorter bout lengths and lower frequency of longer bouts measured with the ActiGraph compared to the *activ*PAL™. While children's age range was wider in the ActiGraph patterns analysis, age was adjusted for and is therefore unlikely to account for the difference in the results.

Accelerometers have been used in several large scale studies to assess sedentary behaviour (e.g. ICAD, NHANES), and therefore potentially important quantities of data are available for further analysis of children's sedentary patterns. The accurate assessment of sedentary patterns has important implications for future research. This includes informing public health guidelines, development of interventions that aim to change children's sedentary behaviour patterns, evaluation of the effectiveness of interventions and further research as to associations between sedentary patterns and indices of health. Therefore, if accelerometer determined breaks and bouts do not reflect actual interruptions to sitting time, future studies of children's sedentary patterns may need to use devices that directly measure posture, such as the *activ*PAL™.

An important consideration for future research is how to measure bouts of sedentary time so that the information obtained is relevant to the research implications discussed above (i.e. public health guidelines, intervention development and evaluation, and health associations). In this doctoral thesis, a series of pre-determined bout lengths were set with a maximum bout length encompassing an uninterrupted period of 15 minutes or more. The frequency of each bout (2-5, 5-10mins, 10-15 mins, ≥15 mins) was then assessed. This approach provides important information about how frequently children engage in sedentary bouts of different lengths. The findings from this thesis showed that the frequency of the longest bout length (≥15 minutes), was the smallest. However, it is not known how long the ≥15 minute bout was and it may be that a lower frequency was due to a longer time spent in that bout. For example, a frequency of one long bout/day may be more detrimental to health if it is an hour in duration, compared to a frequency of two long bouts per day that are half-an-hour each. In order to further understand the health implications of longer uninterrupted bout lengths it may therefore be important to measure absolute minutes spent in bouts. Furthermore, in order to individualise children's typical bout pattern, it will be important in future research to assess the average sedentary bout duration. This information can be used in temporal patterns analysis to determine when the average length of a sedentary bout is longer and identify children who have a pattern of sedentary behaviour that encompasses longer sedentary bouts.

Breaks in sedentary time (Actigraph) and sitting time (*activ*PAL^{TM}) increased with higher levels of children's total sedentary time and sitting time, suggesting higher levels of sedentary or sitting time may equate to greater opportunity to break up this time. Therefore, an interesting area for future research would be to assess the fragmentation rate adjusted for the total sedentary time or sitting time (e.g. total breaks by sedentary/sitting time). Among adults, this has previously been examined as average breaks/sedentary hour (Healy et al. 2008); however, to the candidates knowledge, this fragmentation has not been examined in children.

Screen time as a proxy for sedentary and sitting time

This thesis presents some of the first methodological evidence looking at the measurement of time spent in different SBBs and total screen time as an indicator of overall and patterns of sedentary and sitting time. Given the dominance of screen time, in particular TV viewing as an indicator for sedentary behaviour in studies to date, it is an important finding that time spent in SBBs was not a good indicator of children who engage in higher levels of sedentary time or differences in the pattern of accumulation of sedentary time. However, time spent in TV viewing on weekend days may reflect higher levels of sitting time and longer uninterrupted bouts of sitting time on weekend days among girls. Therefore, behavioural questions about girls' TV viewing time may be useful in identifying girls at risk of sedentary lifestyle during discretionary weekend time. However, as discussed above, given the rapid emergence of new screen-based technologies and the opportunity to multimedia task, future research will need to expand the measurement of SBBs to reflect this change. In addition, further research using a direct measure of posture, such as the *activ*PAL™ is needed with studies encompassing a larger and more diverse sample of children.

When to intervene

The results of the current study indicate periods of the school day and discretionary weekday and weekend day times may be important for health promotion targets to reduce overall sedentary time. School is often considered an important setting for targeting health promotion because the inherent nature of school-based learning often requires prolonged periods of sitting at a desk in class, whereas break time (recess and lunch time) represents an important opportunity for physical activity (Ridgers et al. 2012). The distinctly higher percentage of sedentary time in class periods, identified in Chapters 5 and 6, supports this notion and highlights a key issue of a need to reduce sedentary time during this period. However, the high level of sedentary time during the weekday after school and evening periods as well as the consistently high percentage of sedentary time across all periods on a weekend day suggests that targeting children's discretionary leisure time will also be important. Given the limited associations between children's sedentary/sitting time and screen time observed in this thesis it will be important for future research to further explore what children are doing in their leisure time so that targeted interventions can be developed.

In light of the emerging scientific evidence of the beneficial associations of breaking up sedentary time to health (Dunstan, Kingwell, et al. 2012; Healy, Dunstan, et al. 2008) and public health awareness of the importance of breaking up sedentary time (The Department of Health 2014), health promotion strategies are likely to encompass breaking up sedentary time as well as reducing total sedentary time. However, as previously discussed, an important consideration for future research will be to determine the accuracy of the ActiGraph and the *activ*PAL™ in measuring breaks in and bouts of children's sedentary and sitting time. This will be particularly important for the accurate identification of the key periods in which to intervene on children's sedentary behaviour.

In addition, a consideration for future research is the influence of seasonality on children's sedentary behaviour patterns. Positive associations have been reported between total sedentary time and seasonality in children (Hjorth et al. 2013) and adolescent females (Gracia-Marco et al. 2013) with higher levels of sedentary time during winter in comparison to spring. These studies are limited to accelerometer determined sedentary time and only assess overall daily sedentary time. Repeated measures across different seasons using direct measures of posture are needed to provide a more accurate assessment of children's sedentary patterns and therefore the key periods in which to intervene.

Measures of CVD risk factors

The smaller sample of children who consented to and provided a blood sample in comparison to the total study group suggests that less invasive measures of CVD outcomes are needed. Examples of such measures include pulse wave velocity (Jadhav & Kadam 2005), determined by flow mediated dilation, and retinal analysis . Furthermore, the limited evidence of associations between sedentary behaviour and CVD risk factors in this thesis may be explained by the shorter 'lifetime' exposure to sedentary behaviour in young people and the pathophysiological development of CVD risk factors which are more distal compared to older age groups. In addition, the average frequency of health enhancing breaks and shorter bouts among children in the current study was high which may make it difficult to identify health associations in this age group. Therefore it may be important to identify less invasive approaches that can detect early pathological changes, such as endothelial dysfunction and retinal analysis (Owen et al. 2011).

Endothelial dysfunction is recognised to be centrally involved in both the initiation and progression of CVD (Glass & Witztum 2001). Several studies have shown strong correlations between endothelial dysfunction and sub-clinical markers of atherosclerosis, such as the Bogalusa Heart Study, in which obesity during childhood was associated with 25% increased risk of being in the top quartile of intima media thickness in adolescence (Chen et al. 1999). Pulse wave velocity (PWV) assesses the speed of the blood pressure wave to move between a set distance (Jadhav & Kadam 2005). As such the measurement encompasses several parameters including endothelial elasticity, wall thickness and blood density, collectively referred to as endothelial function.

An emerging non-invasive approach to assessing CVD risk in children is that of retinal analysis which involves measuring the tortuosity of the retinal arteriole from digital images (Owen et al. 2011). Changes in the retina microcirculation have been observed with risk factors for CVD, including increased blood pressure (Leung et al. 2003) and BMI in adults (Wong et al. 2006). In child studies, strong associations have been reported between blood pressure (Mitchell et al. 2007), BMI (Cheung et al. 2007) and retinal arteriolar calibre, which are similar to those reported in adults (Leung et al. 2003; Wong et al. 2006). More recently the Child Heart and Health Study in England (CHASE) of 10-11 year olds examined the association between tortuosity and a range of cardio-metabolic risk factors, including biomarkers (Owen, CG et al. 2011). The authors reported a significant and positive association between arteriolar tortuosity, SBP, DBP, TC, TG and LDL-C. The non-invasive measures described here may represent a more favourable approach to the identification of early stages of the pathogenesis of atherosclerosis in child populations than taking blood samples.

11.4 Conclusions

This thesis found that primary school children engage in high levels of screen time and objectively measured sedentary and sitting time. This highlights the importance of establishing healthy behaviours early in life and suggests key intervention time points, including school class time and weekend periods. Considering the aetiological evidence of the early origins of CVD it is concerning that, although limited, there was some evidence of adverse associations between sedentary behaviour and CVD risk factors among this young age group as well as evidence of children with elevated risk factors.

Further investigation of the relevance of sedentary behaviour, including breaks in and bouts of sedentary behaviour to CVD health is needed to inform and maximise the effectiveness of public health strategies and interventions. The results presented in this doctoral thesis suggest that the sedentary measures used in this doctoral thesis are assessing different dimensions of sedentary behaviour. Interestingly though, the temporal patterns found with both objective devices showed a very similar pattern with distinct peaks in sedentary/sitting time during class periods compared to a consistently high level of sedentary time across all periods of the weekend day which has important implications both for school and family based interventions. Furthermore, although the measurement of specific SBBs does not likely reflect accelerometer determined sedentary behaviour, it may be more indicative of *activ*PAL^{TM} determined sitting time, particularly with regard to TV viewing among girls. Further research is needed which encompasses a wider range of SBBs and examines the relevance of these behaviours to children's sitting time with less invasive health indices.

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List of Appendices

Appendix A: Screen-based behaviours and CVD risk factors

A.1 Synthesis of screen-time and adiposity review papers

A.2 Synthesis of studies of screen-time and CVD risk factors

	Search strategy and year range	Quality assessment	Inclusion criteria	Exclusion criteria	Results/conclusions	Limitations
(Tremblay et al. 2011) Meta-analysis and narrative N=170	Medline – 1950 to Feb week 2, 2010. Embase – 1980 to week 7, 2010. PsycINFO - 1806 to Feb week 3, 2010. Created by single researcher and run by a second researcher. .	Inter-rater reliability calculated using Cohen's kappa. Quality of evidence determined by study design and Downs and Black 27 point checklist[*1]	All study designs Age 5-17 years. Sample size ≥ 300 observation studies Sample size ≥ 30 RCT's. Measured sedentary behaviour (direct/objective or self-report) and a specific health outcome. Longitudinal studies encompassing the target age group. Measured body composition, metabolic syndrome or cardiovascular disease risk factors.	Studies involving active gaming. Ineligible population, exposure, measure of sedentary behaviour, outcome, analysis or other.	**RCTs:** meta-analysis effect of –0.89 kg/m2 decrease in mean BMI in the intervention group. **Interventions and longitudinal studies**: Dose response relationship **Cross sectional studies:** Association between > 2 hrs/TV and increased risk overweight/obese.	Results/conclusions made about TV viewing as a whole. No differentiation between objectively measured SB, TV viewing, computer use, and video games. Likely to have inadvertently included studies involving active gaming. No breakdown of age groups or direct compared to self-report measures of SB. Used Down and Blacks but not clear how it is incorporated into quality of evidence by way of results, conclusions or discussion (with the exception of excluding studies with small sample size based on Down and Blacks).
(Chinapaw et al. 2011) Systematic N=31	1 January 1989 – April 2010 PubMed, EMBASE, PsycINFO,	Best evidence synthesis: 13 quality criteria based on population and participation (baseline), attrition, data collection	Longitudinal studies Age < 18 years Examined longitudinal relationship between sedentary behaviour		4/6 high quality studies + assn. 5/10 studies + relationship between sedentary time and indicator of fat mass	Wide age range. Some comparison of boys and girls for sedentary time as a whole (i.e. no

	Cochrane Library.	and data analyses	(assessed during youth) and biomedical health indicators (assessed during youth or adulthood). Full text articles in English.		"Insufficient evidence for a positive longitudinal relationship between sedentary time and BMI."	differentiation of types of sedentary behaviour) but not age group or type of sedentary behaviour. + conclusions based on sedentary time (not just TV). Not clear as to length of follow up that conclusions are based on.
(Rey-Lopez et al. 2008) Narrative N=71	1990-April 2007 *Data bases* – Medline and PubMed *Search terms* – obesity, adiposity, child, adolescent, sedentary behaviour, television viewing, video games, internet use, sitting time	NA	Cross-sectional, longitudinal and intervention studies Age 2 – 18 years Measure of body composition Measure of sedentary behaviour	No measure of body composition	Sufficient evidence to recommend setting a limit to time spent watching TV, especially among younger children. Video game and computer use do not represent such high risk (compared to TV viewing) if not replacing too much physical activity.	No quality assessment. No exclusion based on methodological weaknesses. Ages for specific conclusions not specified. + Differentiated by types of media. Some comment on age and sex differences.
(Kamath et al. 2008) Meta-analysis N=34	Database inception until February 2006. Medline, ERIC, EMBASE, CINHAL, PSYCInfo, DISSERTATION	Adequacy of concealment of allocation; blinding of health care providers and data collectors; analysis of intention to treat principle; extent of loss to follow up.	Age 2-18 years. Randomised controlled trials. Assessment of impact of intervention on lifestyle behaviour and obesity (BMI).	RCT's with patients with eating disorders, adult participants or obese participants. RCT's of interventions aimed at reducing	"All modalities of intervention (dietary only, physical activity only or combined lifestyle interventions) yielded similar trivial to small effects on BMI compared with control." P.4612.	Effect of intervention to reduce BMI was a secondary aim. Effects from interventions that aimed to reduce unhealthy dietary behaviour, increase healthy dietary behaviour, increase

	abstracts, Science Citation Index, Cochrane CENTRAL Database of controlled clinical trials. Manual review of reference lists of included articles, review articles and expert suggestions.		Measure of lifestyle behaviour through	cardiovascular disease risk factors, or other consequences of obesity.		physical activity and/or reduce sedentary behaviour where pooled. Whilst a small but statistically significant effect was observed, with high consistency across results, it is not possible from this review to isolate the effects of reduced sedentary behaviour on BMI due to the fact that results from all types of interventions were pooled. Reference only made to BMI. No other measures of body composition discussed.
(DeMattia, Lemont & Meurer 2007) Meta-analysis and narrative. N=12	1966 – February 2005 Medline, Psych Info, Health Star, Cochrane Data Base of Systematic Reviews, Cumulative Index of Nursing, Allied Health Literature	Examination of validity using own criteria comprising 10 questions.	Controlled intervention studies – randomized controlled trials, controlled clinical trials, comparative studies, and multi centre studies. Subjects included children or adolescents. Intervention reduced sedentary behaviour or controlled weight by way of a reduction in sedentary behaviour. Multi-level interventions,	Studies of behaviour within a controlled laboratory.	4/6 clinic studies + assn. 2/3 population studies+ assn. Interventions with an emphasis on sedentary behaviour are associated with improvements in weight; although the magnitude of change was modest. "The consistent directionality of the effect across very heterogeneous studies does suggest that efforts to reduce sedentary behaviour should be employed as a means to	All studies were multi-component making it difficult to estimate the magnitude of the weight change that resulted from a reduction in sedentary behaviour. The three relevant population studies were by the same researchers and US based so limited in their generalisability. Anticipated quantitative assessment

			e.g. diet and exercise were eligible. Outcome included measure of sedentary behaviour or weight.		reduce the prevalence of paediatric obesity." P.80 Decreasing SB important for weight control	was not practical due to heterogeneity of studies. Only reported BMI and percent overweight.
(Must & Tybor 2005) Narrative N=15	Not specified	Not specified	Prospective/observational studies English	Not specified	6/9 + assn. (age ≤ 10) Among older children (aged 12 +) 3/7 + assn. Decreased SB protective against weight gain.	No structure used for search strategy, quality assessment, inclusion and exclusion criteria.
(Marshall et al. 2004) Meta-analysis N=52	1985 - PsychInfo, SportDiscuss, MedLine, Ingenta. Manual search of reference sections from narrative reviews and primary studies.	Not specified	Cross-sectional (43), longitudinal (8), RCT (1) Age 3-18 years Participants younger than 18 years. English papers or abstracts from peer-reviewed journals.	Experimental manipulation of sedentary behaviour, interventions targeting additional sedentary behaviours, single subject cases, measured only body mass, presented data previously published.	96% of effect sizes were positive. Fully corrected effect size, -0.129 Statistically small relationship warrants questioning of clinical relevance.	Small number of studies included proportionate to number available. Several important studies potentially not included due to strict inclusion criteria. E.g. Excluded studies that measured only body mass. + Reported separately on TV/body fat and video/computer use and body fat.

Chinapaw, MJM, Proper, KI, Brug, J, Van Mechelen, W & Singh, AS 2011, 'Relationship between young peoples' sedentary behaviour and biomedical health indicators: a systematic review of prospective studies', *Obesity Reviews*, vol. 12, pp. e621-e32.

Appendix A.1 Synthesis of screen-time and adiposity review papers

DeMattia, L, Lemont, L & Meurer, L 2007, 'Do interventions to limit sedentary behaviours change behaviour and reduce childhood obesity? A critical review of the literature', *Obesity Reviews*, vol. 8, no. 1, pp. 69-81.

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Tremblay, MS, LeBlanc, AG, Kho, ME, Saunders, TJ, Larouche, R, Colley, RC, Goldfield, G & Gorber, SC 2011, 'Systematic review of sedentary behaviour and health indicators in school-aged children and youth', *International Journal of Behavioral Nutrition and Physical Activity*, vol. 8, p. 98.

Appendix A.2 Synthesis of studies of screen-time and CVD risk factors

Study/Design	Screen time measure	Adiposity	BP	Lipids	Covariates	Key findings	Limitations
USA N=6965 Age 6-11 yrs (Dietz & Gortmaker 1985)	Parent report TV Hrs/day	Skinfolds (Obesity ≥ 85th percentile; super obesity ≥ 95th percentile for children of same age and sex)			Environmental, economic and family variables	Children who watched more TV experienced a greater prevalence of obesity or super obesity compared to children who watched less TV	Limited information as to how TV viewing time collected; e.g. weekday, weekend, previous day, usual day etc. Boys/girls combined
Canada N=76 Age 9-11 yrs (Bernard et al. 1995)	Self-report TV Hrs/day	BMI (overweight/obese ≥ 90th percentile)				No assn. between TV and overweight/obesity.	Small sample size Boys/girls combined Limited information on TV measure No adjustment for covariates
USA N=4063 Age 8-16 yrs (Andersen, RE et al. 1998)	Interview TV Hrs/day Wkday/w'end	BMI Skinfolds			Tanner stage	Compared to boys & girls who watched TV < 2hrs/day, boys who watched 2-3 hours and boys and girls who watched TV ≥ 4 hrs had significantly greater BMI and skinfold thickness	Limited adjustment for covariates
Mexico N=461 Age 9-16 yrs (Hernandez et al. 1999)	Self-report TV E-games Hrs/day Wkday/w'end	BMI Skinfolds (Obesity ≥ 85th percentile, US NHANES I ref data from 1971-1974)				Dose response - odds of obesity increased by 12% for each additional hour of TV viewing. No assn. video games	Boys/girls combined (adjusted for sex). No adjustment for covariates
Canada	Self-report	BMI				Among children who watched	TV and e-games combined

N=446 Age 2-19 yrs (Hanley et al. 2000)	TV/e-games Hrs/day Wkday/w'end	(overweight/obesity ≥ 85th percentile, US NHANES III ref data from 1988-1994)				TV/played e-games ≥ 5 hrs/day the risk of being overweight was significantly higher compared to children who engaged in less than 5 hrs/day TV/e-games (OR: 2.52)	Boys/girls combined No adjustment for covariates Wide age range combined
Canada N=198 Age 7-8 yrs (Horn et al. 2001)	Self-report TV E-games Frequency of TV programmes (calculation based on frequency x 45mins) Weekday	Skinfolds				No assn. boys TV and skinfold thickness + assn. girls TV and skinfold thickness	E-games measurement not clear. Weekday only Measurement and data management of e-games unclear Adjustment for covariates unclear
Germany N=60 Age 5-11 yrs (Grund et al. 2001)	Parental report TV Hrs/day Wkday/wend	BMI (overweight ≥ 90th percentile, German database 1991) Skinfolds % BF (BIA)				+ assn. between TV viewing and adiposity	Small sample size Boys/girls combined
USA N=4069 Age 8-16 yrs (Crespo et al. 2001)	Self-report TV Hrs/day (2 days) weekday	BMI (NHANES II and NHANES III, 1963-1965 & 1966-1970 used to establish age and sex specific cut-points)			Race/ethnicity SES Energy intake Physical activity (frequency of leisure time activities that induce sweating or	Higher prevalence obesity significantly and positively associated with girls TV viewing hours No assn. boys	2 day recall Weekday only Not stated what percentiles were established for cut-points to define overweight and obesity

					breathing hard)		
USA N=2791 Age 8-16 yrs (Dowda et al. 2001)	Self-report TV Hrs/day Wkday/wend	BMI (overweight/obese ≥ 85th percentile, CDC Growth Charts). Skinfolds				Among girls who watched TV ≥4 hrs/day the risk of being overweight was significantly higher compared to girls who engaged in less than 4 hrs/day TV (OR: 1.88) No assn. boys	No adjustment for covariates
China N=1385 Age 6-11 yrs (Waller, Du & Popkin 2003)	TV E-games mins/week	BMI (overweight/obesity ≥ 85th percentile, 2000 National Centre for Health Statistics Growth Charts)				Significantly less time spent in TV viewing hours among overweight children compared to non-overweight children	Measurement of TV unclear Weekdays only No adjustment for covariates Boys/girls combined
USA N=1680 Age 4-13 yrs (Attewell, Suazo-Garcia & Battle 2003)	Parent report time diaries TV computer 10min blocks 1 weekday & 1 weekend day	Parent report height and weight BMI, (CDC formula, 2002)			Family background Age Time in outdoor activities	No association TV ≥ 8 hrs/wk Computer significantly associated with higher BMI after adjusting for covariates	Parent reported height and weight Wide age range Boys/girls combined.
Canada N=7216 Age 7-11 yrs (Tremblay & Willms 2003)	Parent report TV E-games Frequency of days and hrs/day	Parent report height and weight BMI (overweight/obese based on Cole definition)			Age Sex Single or dual parents SES	2-3 hrs/day TV or e-games risk factor for overweight ≥ 3 hrs/day significant risk factor for obesity	Boys/girls combined Parent report height and weight
Australia	Parent report	BMI (overweight/obese			SES	No assn. between TV and e-games/computer after adjusting for	E-games and computer use combined

N=2862 Age 5-13 yrs (Wake, Hesketh & Waters 2003)	TV e-games/ computer hrs/week Usual wkday & w'end day	based on Cole definition)			No. siblings Food intake Organised exercise General activity Parent BMI	covariates in boys or girls	
Switzerland N=872 Age 6-10 yrs (Stettler, Signer & Suter 2004)	Interviewer administered questionnaire TV/e-games Hrs/day weekdays	BMI (Cole definition) Skinfolds			Age Sex Family characteristics TV behaviours, e.g. snacking whilst watching TV	TV and risk obesity (OR: 2.83/hr/day) e-games and risk obesity (OR: 2.03)	Boys/girls combined Weekdays only Not clear how e-games measured
Germany N=668 Age 5-9 yrs (Graf et al. 2004)	Self-report TV Frequency/week	BMI (>90th percentile overweight, >97th percentile obese)				No differences in BMI category between children who watched TV 1-3days/week and children who watched TV 4-6 days/week	Frequency of days not volume of TV time Boys/girls combined No adjustment for covariates
US N=2831 Age 1-12 yrs (Vandewater, Shim & Caplovitz 2004)	Time use dairies (one weekday and one weekend day). TV E-games Computer Hrs/day Wkday/w'end day	BMI (Population specific adjusted CDC Reference charts)			Age Sex Race Highly active and moderate activities	Among 9-12 year olds: + assn. e-games - & + assn. computer (overweight children used the computer either very little or a lot) No assn. TV	Parent report weight Only one weekday recorded Boys/girls combined

Appendix A.2 Synthesis of studies of screen-time and CVD risk factors

US N=192 (girls) Age 5-11 (Davison, Marshall & Birch 2006)	Parent report TV Hrs/day Wkday/w'end day	BMI (overweight ≥ 85th percentile, obese ≥ 95th percentile, CDC 2000 Growth Charts) %BF (DXA)			Pubertal development	No association between TV viewing, BMI, weight status or percentage body fat	Generalisable only to white girls from middle class and well educated families
Canada N=422 Age 5-10 yrs (Chaput, Brunet & Tremblay 2006)	Parent report TV e-games computer hrs/day	BMI (Cole cut-points) WC			Age Sex Parental obesity	Increased odd of overweight/obesity among girls who engaged in ≥ 3hrs/day in TV, e-games or computer use	No adjustment for diet or physical activity Not clear if daily TV included weekend time
Spain N=1375 Age 2-13 yrs (Serra-Majen et al. 2006)	Parent report TV Computer e-games	BMI (age and sex specific percentiles from reference population; overweight ≥ 85th percentile, obese ≥ 97thpercentile. Also used Cole cut-points) Waist and hip circumference			Age Sex Geographical region SES	Compared to children who watched TV < 1hr/day, children who watched 1-2 hrs and > 2 hrs/day TV had significantly higher risk of overweight/obesity	Not clear how time spent in screen based behaviours was ascertained, whether it includes weekend time and whether all behaviours combined or just TV Boys/girls combined
Australia N=1560 Age 5-6 & 10-12 yrs (Salmon, Campbell & Crawford 2006)	Parent report TV Hrs/day (0-6hrs in half hour segments) Wkday/w'end	BMI (Cole cut-points)			Age Child sex SES School clustering Diet	Children who spent > 2 hours/day watching TV had significantly higher risk of overweight/obesity compared to children who spent < 2hrs/day watching TV in unadjusted model No significant association after adjusting for covariates	Boys/girls combined

					MVPA		
Portugal N=3365 Age 7-9 yrs (Carvalhal et al. 2006)	Parent report TV E-games Computer use Hours/day	BMI (Cole cut-points) %BF (DEXA)				Prevalence of obesity increased concurrently with hours of TV viewing for boys and girls up to 4-6 hrs and then decreased at > 6 hrs (not significant for girls) Association between electronic games and BMI for boys and girls	No adjustment for covariates Not clear if weekend time included Overall screen time not examined
USA N=1483 Age 6-19 yrs (Vandewater & Huang 2006)	Self-report diaries TV Hrs/day Wkday/w'end	BMI (0verweight ≥ 85th percentile, obese ≥ 95th percentile, CDC Growth Reference Charts 2000)			SES Maturation Parental obesity	Television viewing hours related to increased odds of overweight/obesity among 6-9 year old boys	Limited covariates Wide age range (although controlled for maturation)
Europe N=1921 Age 9-10 & 15-16 (Ekelund et al. 2006)	Computer based self-report TV Hrs/day Before and after school	BMI (Cole cut-points) Skin-folds	DBP SBP (avg. 3/5 readings)	HDL-C	MVPA Adiposity Sex Age group Study location Sexual maturity Smoking status Birth weight SES	TV viewing was positively associated with skinfolds independent of MVPA	Only measured week day TV viewing Self-report TV Didn't control for diet PA counts, not MVPA Boys/girls combined

Europe N=12538 Age 8-13 yrs (te Velde et al. 2007)	TV computer Hours/day Week	BMI			SES	High TV viewing during dinner and >2hrs/day associated with overweight among boys No association for computer use	Parent reported height and weight Selective non-response of BMI (non-responders more likely to be boys, watch TV during dinner and engage in high computer use) Only controlled for SES
India N=598 Age 6-16 yrs (Kuriyan et al. 2007)	TV Hrs/day Week	BMI (Cole cut-points) Waist and hip circumference			Age Sex Living location SES Consumption of fried foods Sleep duration Rigorous activities	TV viewing associated with overweight. Adjusted odds of being overweight was 19.6 for children who watched more than 1.5 hrs tv/day compared to kids who watched <45 mins/day	Significant but large confidence interval OR=19.8, p<0.001, 95% CI 5.4, 71.9 Limited information about TV viewing measure Not clear if reported rigorous activities adjusted for. Boys/girls combined
US N=546 Age 4-17yrs (Pardee et al. 2007)	Parent report (< 8 yrs) Self-report (8-17 yrs) TV Hrs/day Week	BMI (obesity $\geq 95^{th}$ percentile)	DBP* SBP* (avg. 2 readings)		BMI Race Testing site	Positive correlation between TV time and severity of obesity. Amount of TV associated with increased unadjusted odds of hypertension. Slight reduction after controlling for BMI but still significant	No measure of dietary behaviour or SES. Only obese children Boys/girls combined Only 2 measures BP
Australia N=1943 and1151	Parental report TV & e-games/computer	BMI (Cole cut-points)				TV: At both time points mean hours of TV and total screen time were higher among overweight girls and higher	E-games & computer combined No adjustment for covariates

Age 5-13 yrs (Hesketh et al. 2007)	Hrs/day Wkday/w'end day					again amongst obese girls. The same trend was observed among overweight but not obese boys compared to non-overweight boys at both time points. E-games/computer: At time point 1 obese girls spent greater time in e-games/comp compared to non-overweight girls. No assn. for boys. Total screen: At both time points mean hours of total screen time were higher among overweight girls and higher again amongst obese girls. The same trend was observed for screen time among overweight and obese boys at time point 2.	
USA N=2343 Age 9-12 yrs (Adachi-Mejia et al. 2007)	Self-report Frequency TV weekday TV in bedroom Monthly use of internet	BMI (0verweight ≥ 95th percentile)			SES Parent reported frequency of physical activity TV and internet frequency	TV in bedroom increased risk of overweight (OR: 1.32) No assn. between TV viewing or internet frequency and weight status	Parent reported height and weight TV frequency not volume Weekday only Boys/girls combined
France N=1016 Age 3-14 yrs (Lioret et al. 2007)	Reported TV/e-games Hrs/day Wkday/w'end	BMI (Cole cut-points)			Leisure time physical activity (questionnaire) SES	Among 6-14 year olds, children in the intermediate group (20th-80th percentile for screen time) OR:2.2 and children in the high level group (>80th percentile) OR: 2.3 compared to the low level group (<20th percentile)	TV/e-games combined Not stated if self- or proxy report Boys/girls combined Wide confidence intervals, close to 1.

							2.2 (1.2-4.1) 2.3 (1.1-4.8)
USA N=709 Age 7-12 yrs (Laurson et al. 2008)	Reported TV/e-games Hrs/day Wkday/w'end	BMI (Cole cut-points)			Age	NS for boys or girls meeting screen time rec (<2 hrs/day) compared to those exceeding guidelines	TV/e-games combined. Not stated if self- or proxy report.
Brazil N=4452 Age 10-12 yrs (Wells et al. 2008)	Self-report TV Hrs/day Wkday/w'end	BMI Skin-folds	DBP* SBP* (avg. 2 readings)		SES Sex Birth weight Birth length PA	TV viewing was associated with increased BMI, skinfolds, SBP and DBP	Only 2 BP measures. No adjustment for diet. TV only Adjusted for PA but not objective - questionnaire based leisure time PA and mode of usual transport. Boys/girls combined
USA N=10663-3843 Age 6-11 yrs (Fulton et al. 2009)	Parent report TV Computer Hrs/day Previous day	BMI (Overweight/obese ≥ 85th percentile, CDC Growth Charts 2000)			Race Sex BMI	TV – No assn. Computer – No assn. Screen – Boys - no assn. Girls – those who spend more than	Only measured TV/computer viewing the day before (not specified if week day or weekend day

						4.5 hrs/day in TV & computer use were 1.7 times more likely to be overweight compared to girls whose TV/comp time was less than 2 hrs/day	
Cyprus N=622 Age 10-13 yrs (Lazarou, Panagiotakos & Matalas 2009)	Self-report TV Hrs/day Wkday/w'end		DBP SBP		PA Diet Adiposity	No assn. between TV viewing time (<2hrs compared to >2hrs) and BP	Only one measure of BP taken No measure or adjustment for puberty Boys/girls combined Measurement BP not clear.
Australia (Ballarat) N=393 Age 9-11 yrs (Aucote & Cooper 2009)	Parent report TV E-games Hrs/day Wkday/w'end	BMI (CDC Growth Charts, 2000)				TV viewing positively predicted zBMI .	TV and video game as combination may have different metabolic effects. Single height and weight by one researcher. Limited generalisability.
USA N=111 Age 3-8 yrs (Martinez-Gomez, Tucker, et al. 2009)	Parent report TV Computer/e-games Mins/day Wkday/w'end day	%BF (DEXA)	DBP* SBP* (avg. 3 readings)		Sex Age Height SES % BF	Association between body fat and SBP and DBP TV + assn. with SBP and DBP Computer use no sig assn. Screen time + assn. with SBP not DBP, after adjusting for %BF and socioeconomic status Screen measures and assn. with adiposity not reported	Computer use included e-games. Small sample size. Boys/girls combined (adjusted for sex).

USA N=69031 Age 6–17 yrs (Russ et al. 2009)	Parent report TV/e-games Computer Hrs/day Weekday	Parent reported height and weight BMI (≥95th percentile, 2000 CDC Growth charts)			Race Sex Age SES No. children in household Family structure Mothers mental health Neighbourhood safety	Bivariate model – TV and combined media but not computer use associated with greater odds of overweight/obese Multivariate – TV, computer use and combined screen associated with greater odds of overweight/obesity. Smaller association compared to bivariate model	Weekdays only Parent reported height and weight TV e-games combined Boys/girls combined
England N=6337 Age 9-10 yrs (Fairclough et al. 2009)	Self-report TV E-games Internet Hrs/day Wkday/w'end	BMI (Cole cut-points)			Analysis undertaken within 4 SES groups	No consistent association between screen behaviours and overweight/obesity	Limited adjustment for covariates
Cyprus N=1140 Age 9-13 yrs (Lazarou & Soteriades 2010)	Self-report TV Hrs/day Wkday/w'end	BMI (Cole cut-point) WC (≥ 75th percentile)			Self-reported physical activity Diet quality score SES Age Place of residence	Girls who spent > 4 hrs watching TV were 2.84, 3.25 and 3.63 (OR) more likely to be overweight/obese (BMI), WC >75th, body fat >30%, respectively compared to girls who spent 1 hour per day watching TV. Boys – no assn.	

Greece N=410 Age 7-15 yrs (Papandreou, Malindretos & Rousso 2010)	Parent report TV Hrs/week Wkday/w'end	BMI (Cole cut-points)			Multivariate model Breast feeding Family history of obesity Leisure time physical activity (questionnaire) Fruit and vegetables Sugar-sweetened beverages	Overweight/obese children spend significantly more time watching TV/week compared to the healthy weight control group Greater odds of overweight/obesity in univariate and multivariate models	Boys/girls combined No SES adjusted for
Spain N=425 Age 13-18.5 yrs (Martinez-Gomez et al. 2010)	Self-report TV Usual amount/day	BMI (Cole cut-points) WC		TC HDL-C* LDL-C	Age Sex Puberty Race Weight status SES	High TV viewing group (>3hrs) had less favourable HDL-C compared to low TV viewing group (<3hrs)	Didn't control for MVPA or diet TV viewing only No dose response Boys/girls combined
Korea N=845 Age 10-18 yrs (Hee-Taik et al. 2010)	Self-report TV/computer Hrs/day Wkday/w'end	BMI WC (Obesity based on cut-points of the 2005 Korean Pediatric Society)	DBP* SBP*	TC* HDL-C*	Age Sex SES	Mean BMI, WC, SBP, TC and TG increased as the quartile for screen time increased.	BP - average of two readings No control for important confounding factors No measure of puberty Boys/girls combined
Canada N=11658	Parent report TV	BMI (Cole cut-points)			Sex of child Age	Each 30 minute increase in time spent watching TV increased the odds of overweight and obesity	Parental report of height and weight TV only measured between after

Age 5-19 yrs (Tudor-Locke et al. 2011)	Hrs & mins/day Weekday (after school - dinner)				SES		school and dinner time Boys/girls combined
United States N=2527 Age 6-19 yrs (Carson & Janssen 2011)	Parental proxy-report (6-11 years) Self- report (12-19 years). TV Computer Usual time/day over the past 30 days	WC (not defined)		TC Non-HDL-C	Age Sex Ethnicity Smoking Diet MVPA Adiposity	High TV (≥4hrs compared to <1hr), but not computer use associated with WC, SBP and non-HDL-C in boys/girls combined	No breakdown of age groups and no control for pubertal status Lipids not fasted measure Boys/girls combined No overall measure of screen time

APPENDIX B: Summary table of accelerometer determined sedentary time and CVD risk factors

B.1 Synthesis of studies of sedentary time and CVD risk factors

Study/Design	Accelerometer data management	Adiposity	BP	Lipids	Covariates	Key findings	Strengths	Limitations
Studies of volume and patterns of sedentary time								
(Carson et al. 2014) (BEAT) Canada N=1704 Age 10-11 years	Total sedentary time, breaks and bouts (20, 40, 60, 80, 100, 120) ≤100 cpm 5-s epoch ≥600 mins wear time/day ≥4 days (inc.1 w/e day) Non-wear: 60 mins consecutive zero's	BMI			Age Sex SES MVPA (≥4 METs) (total sedentary time – for breaks analysis)	Weekday bouts of 5-9 minutes positively associated with BMI. Weekend day bouts of 1-4 and 5-9 minutes positively associated with BMI. No assn. between total sedentary time or breaks in sedentary time and BMI.	Large sample size Controlled for MVPA	High threshold for non-wear time No controlling for diet in analyses
(Cliff et al. 2013) HIKCUPS Australia N=126 Age 5.5-9.9 years	Total sedentary time, average number of sedentary bouts/day, 10, 20 and 30 minute bouts ≤100 cpm 60-s epoch	WC	SBP DBP	HDL-C LDL-C TC TG CMR-score (the sum of	Age Sex WC Energy intake MVPA (≥2296 cpm)	Inverse assn. between total sedentary time and HDL-C in overweight and obese children. Participants in the highest quartile for > 30 minute bouts had significantly lower HDL-C compared to	Controlled for MVPA, energy intake and WC	Not clear if weekend day included Small sample size Overweight and obese children only included in sample

	≥ 600 mins wear time/day ≥3 days (inc.1 w/e day) Non-wear: ≥ 20mins consecutive zero's			standardised residual of TG, inverted HDL-C, MAP, HOMA-IR onto age and sex)		the lowest quartile.		
(Colley et al. 2013) Canadian Health Measures Survey Canada N=1608 Age 6-19 years	Total sedentary time, breaks and bouts (1-4, 5-9, 10-19, 20-29, ≥30 mins) on weekend days and after 3pm on weekdays. 20% forgiveness rule. ≤100 cpm 60-s epoch ≥600 mins wear time/day ≥4 days (inc.1 w/e day) Non-wear: 60 mins consecutive zero's with 2 minutes of allowance of counts 0-100	BMI WC		Non-HDL-C	Age MVPA (≥1500 cpm) Accelerometer wear time	Boys: + assn. ≥ 40 minute bouts on weekdays and WC; + assn. ≥ 80 minute bouts, BMI and WC in 11-14 year olds; - assn. between breaks on weekdays and WC in 11-14 year olds; + assn. between each additional 60 minutes of sedentary time on weekdays and WC in 11-14 year olds. Girls: null associations with total sedentary time, bouts or breaks and CVD risk factors.	Large sample size Associations examined for different age groups: 6-10, 11-14, 15-19 years Controlled for MVPA	High threshold for non-wear time No adjustment for diet in analyses Calculation of bout length included 20% of time above 100cpm Weekday time limited to after 3pm

(Chinapaw et al. 2012) ENERGY-Project Hungary, The Netherlands N=142 Age 10-12 years	Total sedentary time and number of sedentary bouts <100cpm 15-s epoch ≥600 mins wear time/day (we) ≥480 mins wear time/day (we) ≥4 days (inc.1 w/e day) Non-wear: ≥20mins consecutive zero's	BMI WC		HDL-C LDL-C TG CMR-score (the sum of glucose, c-peptide, TC, HDL-C, LDL-C,TG)	Sex Country Number of sedentary bouts MVPA (≥3000 cpm) WC	Children in the highest quartile for sedentary time had significantly greater BMI and WC compared to children in the lowest quartile No assn. between the number of sedentary bouts and CVD risk factors. No assn. with CMR-score		Small sample size Only adjusted for covariates in analysis when CMR-score was the outcome. No measure of diet energy density
(Carson and Janssen 2011) NHANES US N=2527 Age 6-18 years	Total sedentary time, breaks and ≥ 30 minute bouts. 20% forgiveness rule <100cpm 60-s epoch ≥600 mins wear time/day ≥ 4 days (inc.1 w/e day)	WC	SBP	TC Non-HDL-C CMR-score (the sum of WC, SBP, TC, non-HDL-C)	Age Sex Ethnicity Smoking Diet MVPA (≥200 cpm) Adiposity	Volume of sedentary time, 30 min bouts of sedentary time and breaks in bouts of sedentary time were not associated with CVD risk factors	Large sample size Controlled for MVPA, diet and puberty. Adiposity - WC	30 minute bout allowed 20% minutes above 100 cpm

	Non-wear: 20mins consecutive zeros							
Studies of volume of sedentary time (cross-sectional studies)								
(Chaput et al. 2013) QUALITY Montreal, Quebec, Sherbroke (Canada) N=536 Age: 8-10 years	≤100cpm 60-s epoch ≥600 mins wear time/day ≥4 days (inc.1 w/e day) Non-wear: ≥60 mins consecutive zero's	WC	SBP DBP	TG HDL-C	Age Sex Sleep duration Diet SES Sexual maturation	No assn. between sedentary time and CVD risk factors.		High non wear criteria: ≥60 mins consecutive zero's
(Cliff et al. 2012) HIKCUPS Australia N=126 Age 5.5-9.9 years	≤100cpm 60-s epoch ≥600 mins wear time/day ≥3 days (inc.1 w/e day) Non-wear: ≥20 mins consecutive zero's			HDL-C LDL-C TC TG	Age Sex WC Energy intake MVPA (≥2296 cpm)	Inverse assn. between total sedentary time and HDL-C in overweight and obese children.	Controlled for MVPA, energy intake and WC	Not clear if weekend day included Small sample size Overweight and obese children only included in sample
(Chaput et al. 2012) QUALITY	≤100cpm 60-s epoch	% body fat Waist-to-			Age Sex	No assn. between total sedentary time and adiposity	Controlled for a wide range of covariates	High non wear criteria: ≥60 mins consecutive zero's

Montreal, Quebec, Sherbroke (Canada) N=550 Age 8-10 years	≥600 mins wear time/day ≥4 days (inc.1 w/e day) Non-wear: ≥60 mins consecutive zero's	height ratio			Sleep duration Diet SES Sexual maturation			
(Hay et al. 2012) Healthy Hearts Alberta, Canada N=156 Age 9-17 years	<100cpm 15-s epoch ≥480 mins wear time/day ≥3 days (inc.1 w/e day) Non-wear: 60 mins consecutive zero's	BMI WC	SBP		Age Sex LIPA, MPA and VPA (MPA and VPA ≥1500 cpm)	No assn. between total sedentary time and CVD risk factors.		Over adjustment of all intensities of physical activity. No adjustment for diet High non wear criteria: ≥60 mins consecutive zero's
(Ekelund et al. 2012) ICAD Australia, Brazil, Europe, US N=6413 Age 4-18 years	<100cpm 60-s epoch ≥500 mins wear time/day ≥1 day (inc.1 w/e day) Non-wear: 60 mins consecutive zero's with 2 minutes of	WC	SBP	HDL-C TG	Age Sex MVPA (≥3000 cpm) Accel. Wear mins Height (for SBP)	No assn. between total sedentary time and CVD risk factors.	Large sample size encompassing data from several countries	Only one valid day of wear time required High non wear criteria: ≥60 mins consecutive zero's No measurement of diet

	allowance of counts 0-100							
(Aires et al. 2010) Spain N=111 Age 11-18 years	<500 cpm 60-s epoch ≥600 mins wear time/day ≥4 days (inc.1 w/e day) Non-wear: 10mins consecutive zero's	BMI			Age Sex LPA, MPA, VPA, VVPA and MVPA (≥3000 cpm) Cpm CRF	No assn. between total sedentary time and BMI, overweight or obesity.		Over adjustment of all intensities of physical activity. High accelerometer count cut-point to define sedentary No adjustment for diet
(Martinez-Gomez et al. 2009) AFINOS Spain N=210 Age 13-17 years	<100 cpm 60-s epoch ≥600 mins wear time/day ≥4 days (inc.1 w/e day) Non-wear: 10mins consecutive zero's	Skin-folds WC	SBP DBP	TG TC HDL-C LDL-C	Age Sex Sexual maturation Race Weight status	Highest tertile of sedentary time positively associated with higher SBP and TG compared to lowest tertile.	Appropriate data reduction (except non-wear time) Fasted blood sample Controlled for adiposity Adiposity – skin-folds and WC	Did not adjust for MVPA or diet Small sample size Adolescents Non-wear criteria low: 10 mins consecutive zeros
(Mitchell et al.2009) ALSPAC UK N=5595	≤199 cpm 60-s epoch ≥600 mins wear time/day ≥3 days wear (inc. 1 w/e day)	BMI DXA			Child sex SES Maternal smoking in pregnancy Birth weight	Odds of obesity increased per hour of sedentary time in minimally adjusted models No longer significant after adjusting for MVPA for boys or	Large sample size of 12 year-old children Controlled for important confounders including puberty and 15 mins MVPA	Greater compliance among non-obese children. No measure of diet No definition of non-wear time

Age 12years					Gestational age Sexual maturation ≥ 8 hrs TV/week at 38 months ≥ 10.5 hrs sleep/night at 30 months 15 mins MVPA/day (≥3600 cpm)	girls		
(Steele et al. 2009) SPEEDY UK N=1862 Age 9-10 years	<100 cpm 5-s epoch ≥500 mins wear time/day ≥3 days wear Non-wear: 10mins consecutive zeros.	BMI WC Fat mass index			Age Sex SES Birth weight Maternal BMI Sleep duration WC MVPA (≥2000 cpm)	Boys and girls combined: + assn. WC and fat mass index, no longer significant after adjusting for MVPA	Large representative sample among 9-10 year olds Controlled for MVPA	Not clear if wear time limits included any weekend days Several important confounders adjusted for but not diet
(Thompson et al. 2009)	≤1 MET 60-s epoch	BMI			No covariates	No assn. between mean sedentary minutes and weight	Compared boys and girls	No adjustment for important confounding factors

PACY-2 Canada N=1790 Age 7-17 years	≥240 mins wear time/day ≥5 days wear (inc. 1 w/e day)					category for boys or girls in any age group	Large, representative sample Adiposity measure, BMI	Data reduction only included 4 hours wear time per day BMI only Grades 3, 7, 11 combined- (ages 7-17); no measure/control for puberty
(Purslow et al. 2008) PEACHES UK N=301 Age 8-9 years	<100 cpm 60-s epoch ≥600 mins wear time/day ≥3 days wear (inc. 1 w/e day) Non-wear: 10mins consecutive zero's	BMI WC Fat mass index			No covariates	No association between sedentary time and weight status among boys or girls	Controlled for sex, SES and ethnicity Compared boys and girls	Limited generalisability among 8-9 year olds children. No adjustment for important confounding factors. Non-wear: 10mins consecutive zero's
(Ekelund et al. 2007) EYHS Europe N=1709 Age 9-10 & 15-16 years	<500 cpm 60-s epoch ≥ 600 mins wear time/day ≥4 days (inc.1 w/e day) Non-wear: 10mins consecutive zero's	Skin-folds WC	SBP DBP	HDL-C TG CMR-score (WC, DBP, SBP, glucose, insulin, inverted	Age group Sex Study location WC CRF	Weak but positive correlation between total sedentary time and SBP, DBP, TG, and skinfolds. No correlation with HDL-C or WC. Positive assn. between total sedentary time and SBP, DBP, TG and CMR-score. No assn.	Controlled for CRF Large sample size Adjusted for adiposity Adiposity – skin-folds and WC	Did not control for MVPA, diet or puberty High accelerometer count cut-point to define sedentary Non-wear criteria low: 10 mins consecutive zeros

				HDL-C, TG)		with HDL-C or WC.		
(Hussey et al. 2007) Dublin, Ireland N=224 Age 7-10 years	<100 cpm 60-s epoch ≥3 days wear (inc. 1 w/e day)	BMI WC			Sex Age	Moderate, positive correlation between total sedentary time and WC in boys, not girls. Null association between total sedentary time and WC or BMI.		Daily wear time criteria and non-wear time not specified. No adjustment for important confounding factors
(Treuth et al. 2005) US N=229 Age 7-19 years	<100 cpm 60-s epoch ≥1000 mins wear time/day ≥4 days wear (inc. 2 w/e days)	BMI Fat mass % fat			No covariates	Boys: no associations Girls: BMI/SB + assn. middle and high school girls; fat mass, % fat and SB + assn. in all age groups	Compared boys and girls Measure of body composition Differentiated by sex and age category	Generalisable to rural only No adjustment for important confounding factors
Studies of volume of sedentary time (longitudinal studies)								
(Mitchell et al. 2013) US N=424 Age: 9-15years 6 years follow-up	≤100cpm 60-s epoch ≥600 mins wear time/day ≥3 days Non-wear: ≥60 mins consecutive zero's	BMI			Sex Race Maternal education Hours of sleep Healthy eating score MVPA (≥2296 cpm)	In children at the 90th percentile, each additional hour spent sedentary at baseline was associated with an increase in BMI at 6-year follow-up.	Controlled for important confounders, including MVPA and diet. Longitudinal design	High non wear criteria: ≥60 mins consecutive zero's A weekend day of accelerometer wear time was not required.

(Treuth et al. 2008) TAAG US N=984 Age: 11.9- 13.9 years 2 years follow-up	≤100cpm 30-s epoch ≥360 mins wear time/day ≥1 day Non-wear: imputation based on Expectation Maximization algorithm.	BMI %BF				Increased sedentary activity was not associated with increased BMI or % BF.	Longitudinal design	Not specified if weekend day of wear time was required to be included in analysis. Only one day of valid wear time was required to be included in analysis. Low minimum daily wear time criteria. Did not control for MVPA or diet.

Abbreviations: CRF, indicates cardio-respiratory fitness; BP, blood pressure; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; WC, waist circumference; CMR-score, CMR-score, cardio-metabolic risk score; METs, metabolic equivalents; cpm, counts per minute

Study names: BEAT, indicates Built Environment and Active Transport; HIKCUPS, Hunter Illawarra Kids Challenge Using Parent Support; QUALITY, Quebec Adiposity and Lifestyle Investigation in Youth; ICAD, International Children's Accelerometry Database; AFINOS, Physical Activity as a Preventative Agent of the Development of Overweight, Obesity, Allergies, Infections and Cardiovascular Risk Factors in Adolescents; ALSPAC, Avon Longitudinal Study of Parents and Children; SPEEDY, Sport, Physical Activity and Eating Behavior, Environmental Determinants in Young people; TAAG, Trial of Activity for Adolescent Girls; PACY-2, Physical Activity and Dietary Intake of Children and Youth; PEACHES, Physical Exercise and Appetite in Children Study; EYHS, European Youth Heart Study.

Appendix C: Transform-Us! study materials

DEAKIN UNIVERSITY

School of Exercise and Nutrition Sciences

Melbourne Campus
221 Burwood Highway
Burwood Victoria 3125 Australia
Telephone: 9244 6278 Facsimile: 9244 6017

«Principles_title» «Principles_name» «Principles_surname»
«School_Nam»
«Address»
«Suburb1» «State» «Postcode1»

Dear «Principles_title» «Principles_surname»

My name is Associate Professor Jo Salmon and I am a Senior Research Fellow with the School of Exercise and Nutrition Sciences at Deakin University. With my colleagues, I am conducting research funded by the National Health and Medical Research Council to investigate sedentary behaviours (ie. sitting time) and physical activity among children in the school and home setting and we would like to invite your school to be involved.

There is strong evidence that low levels of physical activity and long periods of time spent sitting are closely linked with increasing rates of unhealthy weight gain, obesity and type 2 diabetes among Australian children, so it is important that we work towards changing these behaviours. Through our intervention study, titled Transform-Us!, we are **aiming to determine the impact of a 2-year, school- and home-based behavioural intervention targeting sedentary behaviour and physical activity alone and in combination, on 8-9 year old children's sedentary behaviour levels, physical activity levels and metabolic and cardiovascular risk factors for health.**

Transform-Us! will be conducted in 24 Melbourne Metropolitan Primary Schools in 2010 and 2011 with a 12-month follow-up period in 2012. We will be targeting children who are entering grade 3 in 2010 and will follow them until they complete grade 5. We would like to invite your school to be involved in this novel intervention study. Please find attached a plain language statement which further details Transform-Us! Please let me know if you would like a copy of the full application to the educational office.

The Transform-Us! project manager Lauren Arundell will call you within the next 7 days to confirm that you have received this request and confirm whether you are able to assist us. In the meantime, if you have any questions please feel free to contact either myself or Lauren.

Yours Sincerely,

Associate Professor Jo Salmon
School of Exercise & Nutrition Sciences
Deakin University
Ph: (03) 9251 7254
Fax: (03) 9244 6017
Email: jo.salmon@deakin.edu.au

Ms Lauren Arundell
School of Exercise & Nutrition Sciences
Deakin University
Ph: (03) 9244 6278
Fax: (03) 9244 6017
Email: lauren.arundell@deakin.edu.au

DEAKIN UNIVERSITY

School of Exercise and Nutrition Sciences
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221 Burwood Highway
Burwood Victoria 3125 Australia
Telephone: 9244 6278 Facsimile: 9244 6017

Transform-Us! Principal plain language statement

Researchers: Associate Professor Jo Salmon[1], Dr Clare Hume[1], Dr Kylie Hesketh[1], A/Prof David Dunstan[2], A/Prof Robin Daly[3], A/Prof Ester Cerin[4], Professor David Crawford[1], A/Prof Kylie Ball[1], Mrs Helen Brown[1],Dr Mai Chin A Paw[5], Dr Marj Moodie[1], Ms Lauren Arundell[1] and Mrs Sarah Bagley[1].

[1] Deakin University, Burwood Australia, [2]Baker IDI Heart and Diabetes Institute, Caulfield Australia; University of Melbourne, Melbourne Australia, [4] The University of Hong Kong; [5]VU Medical Center, Netherlands

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Dear Principal,

We would like to invite your school to take part in this innovative school- and home-based program aimed at promoting physical activity and reducing unnecessary sedentary (sitting) behaviours in Grade 3 and 4 children. 'Transform-Us!' has received approval from the Victorian Department of Education and Early Childhood Development (DEECD), the Catholic Education Office and the Deakin University Human Research Ethics Committee.

This Plain Language Statement contains detailed information about the program. Its purpose is to explain to you as openly and clearly as possible all the procedures involved in this trial so that you can make a fully informed decision whether you will allow your school to participate. Please read this Plain Language Statement carefully. Feel free to ask questions about any information in the document. You are also welcome to discuss the project with colleagues or a health professional.

Once you understand what the program is about and if you agree for your school to take part, you are asked to approach your school's council or board to seek formal approval for the school's participation. You, the Principal, and a representative from the council/board will then need to sign the attached Consent Form. By signing the Consent Form, you indicate that you understand the information and that you give consent for your school to participate. You will be given a copy of the Plain Language Statement and Consent Form to keep as a record.

Note: A brief audit of current classroom and physical activity policies, practices and physical environment will initially be conducted by the researchers to ensure the school meets several eligibility criteria.

Purpose of this study: Physical activity and time spent sedentary (sitting) have a significant impact on children's health. There is emerging evidence to suggest that low levels of physical activity and long periods of time spent sitting are closely linked with the dramatically increased rates of overweight, obesity and type 2 diabetes among Australian children. Research by our internationally renowned team has shown that targeting the school and home environments is very important for promoting health behaviours in children. The aim of Transform-Us! is to determine the effectiveness of a 2-year, school- and home-based program aiming to reduce the amount of time children in Years 3 and 4 spend sedentary (sitting) and to increase their physical activity while at school and at home. In doing so, we hope to see benefits to children's metabolic and cardiovascular risk factors for health.

Participants: A total of 800 children who are entering Year 3 in 2010 from 24 primary schools will participate in this project which is funded for 5 years by the National Health and Medical Research Council (NHMRC). As the program is run over 2 years with an additional 12-month follow-up, these students will be involved for a total of 3 years. Your school has been randomly selected to participate and all Grade 3 students, their parents/guardians and their teachers are invited to contribute to the evaluation of the project.

The Transform-Us! Intervention groups: Once a written consent form is received, your school will be randomised to one of four groups. The intervention consists of school- and home-based components to be delivered to **all Year 3** intervention children in 2010 and **all Year 4** intervention children 2011. The groups are:

1. Program to reduce children's sitting time (SB-I)
2. Program to promote physical activity in children (PA-I)
3. Program to both reduce sitting time and promote physical activity (SB+PA-I)
4. Current Practice (current school practice) (C)

School-based component: In schools allocated to the intervention, the new Transform-Us! program will be delivered to all children entering Grade 3 in 2010 and all children entering grade 4 in 2011. The program has been developed by the research team in conjunction with teachers and according to the **Victorian Essential Learning Standards for Level 3.** The children's classroom teachers will predominantly be responsible for implementing the new program. The researcher will provide the materials and conduct initial and refresher professional development sessions with all Grade 3 classroom teachers throughout 2010 and 2011.

The intervention arms are further outlined below. Please note that **the main class-based components of the programs will not involve significant changes or additions to the content of the children's classes, but rather slight modifications to the delivery of lessons on a regular basis**, as follows:

- SB-I: Increasing the proportion of class time that children spend continuously active by delivering entire class activities standing (eg 30-minute standing lessons) and reducing periods of continuous sitting by including short (2-minunte) 'standing breaks' every 30 minutes during teaching blocks (eg. children stand and discuss the current activity);
- PA-I: promotion of physical activity during recess and lunch times through our provision of additional signage in the school grounds, additional equipment and teacher supervision;
- SB+PA-I: combining the above strategies to both interrupt extended periods of sitting and increase time spent in physical activity during breaks; and
- C: schools are to continue with their current procedures, policy and practice.

Over the two years, class teachers in the SB-I, PA-I and SB+PA-I groups will also deliver to their students a series of 'key messages' developed by the research team, targeted at their intervention arms' relevant behaviours (eg selective viewing, behavioural contracts). The messages are designed to be easily incorporated into the current learning theme and so additional planning will be minimal. The researchers will provide resources, training and advice to assist with this component and teachers are encouraged to incorporate them into their current curriculum. In addition, the researchers will organise eight newsletters and two parent information nights to provide families with information about the program aims and progress and to reinforce the behavioural changes

Home-based component: Teachers will give children regular homework activities which will focus on reducing time spent in sedentary leisure activities at home (SB-I), increasing physical activity at home (PA-I) or a combination of these (SB+PA-I). Ideas and resources will be provided by the researchers and the teachers will be encouraged to adapt their current homework tasks to match the aim of their intervention arm. Examples of such homework include
SB-I: "Switch off the TV ..." contracts, or
PA-I: 'walking around the neighbourhood' tasks that involve both observational (eg. counting letterboxes), and
SB+PA-I: "Switch off the computer and go for a family walk" tasks.

Schools that are allocated to the control group will allow us to evaluate how current practice promotes and impacts children's health. Therefore, they will not be asked to change their normal school curriculum (content and delivery) nor alter the school environment (no schoolyard signage or extra equipment), but will be involved in all of the assessment components of the trial. After the trial's completion, these schools will be offered the full set of Transform-Us! program materials and training to implement if they wish. Schools randomised the the control group will receive donations eg to the Library/Music Program as compensation for their time and as a token of our appreciation.

Evaluation of the new program: In order to assess the program's effectiveness, trained researchers will collect information from children, parents and teachers on four separate occasions over a three-year period: Term 1/2 2010; Term 4 2010; Term 4 2011; and Term 4 2012.

Children: All assessments (except for blood sample) will take place at the school and we ask for access and use of a large room (eg school gym which we will screen for privacy) to perform the assessments in. All assessments (except for blood sample) will be conducted by trained and experiences research staff with a Working with Children Check. We ask that the children's class teachers and at least one extra school staff member are preset during each measurement session; to assist with the supervision of children as not all children will participate in all assessment components. We will work closely with you and your staff to minimise class disruption

Blood sampling will be performed at 1) a Melbourne Pathology Collection Centre; 2) a local community centre; or 3) Deakin University. The sample will be taken by a qualified phlebotomist (who has experience working with children) according to Melbourne Pathology's collection protocols (blood sampled on three occasions only, months 0, 24, 36).

Parents/guardians will be required to indicate on the consent form which component/s they allow their child to participate in. If at any time the child or parent/guardian is not comfortable with one or more of the assessment components, the child **does not have to take part in that component/s.**

The following assessments will be performed:
- A survey (approx 30-45 mins), completed in class time,
- measurement of height, weight, waist circumference,
- clinical blood pressure measurement (on three occasions only, months 0, 24, 36),
- measurement of physical activity (wearing an activity monitor* for 8-consecutive days),
- measurement of sitting time (wearing an activPAL for 3-4-consecutive days),
- measurement of cardiovascular disease and diabetes risk factors via a 21 mL blood sample. We will provide each consenting child with a pathology slip that can be taken to their nominated collection centre where they can have their blood sampled on three occasions only (months 0, 24, 36). The following tests will be conducted: insulin, glucose, insulin resistance, cholesterol, HDL cholesterol, LDL cholesterol, triglycerides and any other identified important obesity related biomarkers.
- Focus groups or interviews to discuss the progress, effectiveness and difficulties with the program at each assessment point (eg. enjoyment and engagement in class, changes in behaviour etc.). These 30-minute focus groups will be audio-recorded for transcription and responses will be coded and analysed for themes. Comments will not be identifiable in any arising publications.

**An activity monitor/accelerometer is a matchbox-sized, lightweight computer device worn on an elastic belt around the waist, which detects movements of the body. An ActivPAL is a small, lightweight device attached to the thigh via a self adhesive sticker, that calculates and categorises children's movement into time spent sitting, standing and walking. These will be worn for 8 days and are no more harmful than wearing a watch.*

Parents/guardians: Consenting parents/guardians will be asked to complete a 30-minute survey on all four occasions in their own time. The survey will provide information about their demographics, their child's sedentary and physical activities and feedback about the program (eg. "Does your child enjoy completing the homework?" "Are you able to find time to help him/her with the activities?"). Parents will also be invited to attend a 30-minute focus group to discuss the progress, effectiveness and difficulties with the program at each assessment point (eg Child's enjoyment and engagement at home, changes in behaviour etc.). These will be audio-recorded and transcribed and responses will be coded and analysed for themes. Comments will not be identifiable in any arising publications

Teachers: Novel methods, such as a class activity calendar, will be used to assess completion of the school based components and any additional teacher time/resources required. Teachers will complete a short 10-15 minute survey asking about their demographics, their students; physical activities and sedentary time and their schools policies and procedures regarding physical activity and sedentary behaviour. In addition, teachers will be invited to attend four (4) 20-minute recorded interviews with the researchers over the course of the trial, one at each assessment point. During these interviews, they will have an opportunity to discuss the progress and effectiveness of the program and any difficulties encountered. The interview recordings will be coded and any identifying information (names, addresses etc) will be removed before the interviews are transcribed. The interviews will be conducted at times suitable for the teachers. All interviews are strictly confidential and identifying information will be stored separately from the transcripts and recordings. The teachers' consent will be sought for participation in these interviews and they will be made aware that if they do not wish to participate, they are not obliged to.

<u>**Possible Benefits and Reimbursement:**</u> This research will provide valuable information about the effectiveness and cost-effectiveness of combined program of school- and home-based methods for reducing sedentary pursuits and increasing physical activity among children. Uniquely, due to the blood pressure measurements and blood samples being taken, the trial will also offer information about the potentially beneficial impact that these strategies may have on children's risk profiles for cardiovascular diseases and type 2 diabetes. **All parents/guardians will also receive personalised reports about their child's measurements after each assessment point if they have consented to data collection, regardless of the trial group they are allocated to.**

Your school will not be paid for your participation in this project, nor will the participating children, parents or teachers. However, a sports pack will be given to the school and where necessary, improvements to or the introduction of line markings will be provided in the school grounds. Participating teachers, parents and children will receive small gifts (eg voucher, balls) as compensation for their time.

<u>**Possible Risks:**</u> We do not see any risks being associated with this trial, as the program is not stressful in any way. Some children may experience temporary discomfort or bruising from the blood sampling. However this should not last

long. Parents will be provided with a patch of a topical anaesthetic cream (EMLA) to apply to their child prior to the blood sampling if required.

If any child or parent/guardian is particularly concerned with the sampling procedure or a reaction experienced by child after the sampling, they will be encouraged to contact the researchers directly for discussion. If necessary, parents will be referred to seek medical advice from the advisory physician for this study and their details will be provided.

Alternatives to Participation: If your school agrees to participate in the trial and is randomised to one of the intervention groups, all children entering Grade 3 in 2010 will receive the two-year program. However, information will only be gathered from children, parents/ guardians and teachers who have agreed to be involved in the assessment components of the trial by signing the relevant consent forms. Teachers are not obliged to participate in the interviews, nor are parents obliged to complete the surveys. As already stated, parents/ guardians may give consent for their child to participate in some, but not all assessment components. During the assessment sessions, children who **do not have consent** will be given an alternative activity and be supervised by a school staff member.

Privacy, Confidentiality and Disclosure of Information: All information collected during the trial will remain strictly confidential and any publications arising from the study will not contain names or other identifying information. Hardcopies of all records will be stored in secure filing cabinets at Deakin University and data stored on computers (password protected) will be accessible to the chief investigators and research staff only.
All information will be stored at Deakin University in a locked filing cabinet and will be retained for a period of at least six years after the trial is completed. After this time, the information will be destroyed by deletion of electronic files and destruction of all paper-based information. We ask that all participants in focus groups respect the confidentiality of other participants.

Results of Trial: Parents will receive a summary of their child's assessment results. In the event that any measurement taken from a child reveals a potential underlying health risk (eg. an elevated blood pressure reading or blood sugar level), the parents/guardians will be informed immediately via a letter or phone call and will be advised to consult a medical practitioner or clinic. Project summaries (with no individuals identifiable) will be provided to teachers, parents and children in each newsletter and at the end of the study.
The findings of this trial may be published in Journal articles, Higher Degree by Research theses, progress reports etc, however only aggregated, non-identifiable information will be used.

This trial will be carried out according to the *National Statement on Ethical Conduct in Human Research* (2007) produced by the NHMRC. The trial will be closely monitored by the Principal Researchers, who will periodically report on the study's progress and findings to the trial's advisory committee, the Deakin University Human Research Ethics Committee, the Victorian DEECD and to the NHMRC.

Participation is Voluntary: Participation in any research trial is voluntary. Your school is not obliged to take part if you do not wish to and is free to withdraw at any stage. The decision about whether your school is going to take part or not, or take part and then withdraw, will not affect the school's or your own relationship with Deakin University in any way.

Further Information, Queries or Problems: If you would like to ask any questions or discuss the Transform-Us! trial before you make a decision about whether or not to become involved, or if at any stage you have any concerns, require further information or wish to withdraw your school's participation, please do not hesitate to contact the Principal Researcher, Associate Professor Jo Salmon or Lauren Arundell (contact details below).

If you understand the trial, would like your school to be involved and have received approval from your school's council/board, please arrange for the attached consent form to be signed and returned by fax (03 9244 6017) or post to Lauren Arundell, School of Exercise & Nutrition Sciences, Deakin University, 221 Burwood Hwy, Burwood, VIC. 3125

Yours Sincerely

A/Prof. Jo Salmon
Ph: (03) 9251 7254
Fax: (03) 9244 6017
Email: jo.salmon@deakin.edu.au

Miss Lauren Arundell
Ph: (03) 9244 6278
Fax: (03) 9244 6017
Email: lauren.arundell@deakin.edu.au

If you would like any independent advice, have any complaints about an aspect of the project or the way it is being conducted or you have any questions about the rights of research participants, then you may contact: Manager, Research Integrity, Deakin University, 221

Burwood Highway, Burwood Victoria 3125, Telephone: 9251 7129, Facsimile: 9244 6581; research-ethics@deakin.edu.au. Please quote project number EC *2009-141*.

DEAKIN UNIVERSITY

School of Exercise and Nutrition Sciences
Melbourne Campus
221 Burwood Highway
Burwood Victoria 3125 Australia
Telephone: 9244 6278 Facsimile: 9244 6017

Transform-Us! Consent form – School participation

I, ……………………………..…………………………………...… (***name***), Principal of

……………………………………………………………………………………………..........……...(***Primary School***)

hereby agree to allow this school to participate in the trial of a new behavioural-change program aimed at reducing sitting time and promoting physical activity among children, to be undertaken by Associate Professor Jo Salmon and associates from the School of Exercise and Nutrition Sciences, Deakin University.

I acknowledge that:

1. I have read and understand the attached Plain Language Statement. I have been given a copy of the description of the study and consent form to keep.
2. The school Council/Board has been made aware of the trial and has given approval for the trial to be conducted in this primary school. The Council/Board freely agrees to allow children entering Grade 3 in 2010, their parents/guardians and their teachers to be invited to participate in the trial.
3. The researchers have agreed not to reveal the participants' identities and personal details, including where information about this project is published or presented in any public form.
4. Aggregated results will be used for research purposes and may be reported in scientific and academic journals and conference meetings.
5. I am free to withdraw my school from this study at any time.

I agree that

1. The primary school MAY / MAY NOT be named in research publications or other publicity without prior agreement.
2. I / We DO / DO NOT require an opportunity to check the factual accuracy of the research findings related to the primary school.
3. I / We EXPECT / DO NOT EXPECT to receive a copy of the research findings or publications.

School Council/Board representative's Name (Print): …………………………………..…………………………………………

School Council/Board representative's signature: ……………………………………….....…...…… ***Date:*** ……………………

Principal Name (Print): ……………………………………………………………..……………………………………………………

Principal Signature: …………………………………………………………………….……..…………. ***Date:*** ……….……………

Researcher: I have given a verbal explanation of the research project, its procedures and risk and I believe that the School principal has understood that explanation.

Researcher's Name (print): ……………………………………………………………………………………..……..…..

Signature: ……….………………..…………………..……………………………….…………......… ***Date:*** ……….………..

DEAKIN UNIVERSITY
School of Exercise and Nutrition Sciences
Melbourne Campus
221 Burwood Highway
Burwood Victoria 3125 Australia
Telephone: 9244 6278 Facsimile: 9244 6017

Dear Parent/Guardian,

We would like to invite you and your child to participate in the evaluation of a new and exciting approach for reducing children's time spent sedentary and promoting physical activity at school and at home.

Your school's Principal and School Council/Board have given approval for your school to take part in an exciting new two-year program called Transform-Us! The program aims to reduce the amount of time children spend sedentary (sitting) and to increase their physical activity while at school and at home. In doing so we hope to see benefits to children's health; and to reduce their future risk of developing type 2 diabetes, heart disease and obesity.

Transform-Us! involves three different program groups and one current practice group. The Transform-Us! program will be delivered by classroom teachers to all children entering Year 3 in 2010 and will continue through Year 4 (in 2011). Children's teachers will deliver the usual curriculum using a new and exciting approach to lesson delivery (e.g., standing lessons, physical activity homework) that will reduce children's time spent sitting and promote physical activity at school and at home. All Transform-Us! components have been adapted or developed by the Deakin research team with reference to the **Victorian Essential Learning Standards for Level 3** and input and guidance from an advisory committee of teachers. The program has been approved by the Victorian Department of Education and Early Childhood Development (DEECD), the Catholic Education Office and the Deakin University Human Research Ethics Committee.

We are inviting every child with written parental consent, to have their physical activity and health assessed at **four time points during the study, (Term 1/2, 2010; Term 4, 2010; Term 4, 2011; and Term 4, 2012).** Children will be invited to wear an activity monitor (to assess physical activity levels), complete a brief survey (about their physical activity), have their height, weight, waist circumference and their blood pressure measured. We will also provide your child with a pathology slip that you can take to any Melbourne Pathology collection centre; to a pre-arranged community health centre; or to the Clinical Facility at Deakin University, Burwood to have your child's blood markers of cardiovascular and metabolic disease risk assessed and also to obtain their blood grouping (type) (Term1/2, 2010, 2011 and 2012 only). As compensation or your time taking your child to the collection centre we will give you a $20 voucher (eg Coles/Myer). We will invite you to complete a brief survey about your current participation in and potential influences on your physical activity and would be grateful if you would pass on the enclosed consent form and 1-page question sheet to your child's other biological parent to complete. In addition, a small number of children and parents will be invited to participate in interviews (which will be tape-recorded and transcribed). We can assure you that the interview and your personal information (name etc) will remain strictly confidential. We ask you to please explain the assessment components to your child to determine his or her interest in participating

Experienced and fully-trained members of our research team (with current Working with Children Checks and Police Checks) will visit the school to conduct all measurements but school staff members, including the children's class teachers, will also be present to supervise the children – both those being measured and those who do not have consent to participate. We will be working closely with your school to ensure minimal disruption on these days.

Participation in assessment of this program is voluntary; you and/or your child are not obliged to take part if you do not wish to. Your decision about whether you and/or your child take part or not, or take part and then later withdraw, will not affect your relationship with your child's school or with Deakin University in any way. Please find enclosed with this letter:

- a Plain Language brochure detailing the research project and your rights as a participant so that you can make an informed decision about whether to participate in the evaluation of this study
- a consent form for you and your child's participation in this valuable study

If you have any questions regarding this study please do not hesitate to contact the project manager Lauren Arundell or myself by phone or email (details below).

Yours sincerely

Associate Professor Jo Salmon
School of Exercise & Nutrition Sciences
Deakin University
Ph: (03) 9251 7254
Fax: (03) 9244 6017
Email: jo.salmon@deakin.edu.au

Ms Lauren Arundell
School of Exercise & Nutrition Sciences
Deakin University
Ph: (03) 9244 6278
Fax: (03) 9244 6017
Email: lauren.arundell@deakin.edu.au

If you would like any independent advice, have any complaints about an aspect of the project or the way it is being conducted or you have any questions about the rights of research participants, then you may contact: Manager, Research Integrity, Deakin University, 221 Burwood Highway, Burwood Victoria 3125, Telephone: 9251 7129, Facsimile: 9244 6581; research-ethics@deakin.edu.au. Please quote project number EC *2009-141*.

DEAKIN UNIVERSITY

School of Exercise and Nutrition Sciences

Melbourne Campus
221 Burwood Highway
Burwood Victoria 3125 Australia
Telephone: 9244 6278 Facsimile: 9244 6017

ID: _______

Transform-Us! Consent form – Main Parent/Guardian participation

I, …….. of
(*please print parent/guardian's full name*)

……………………………………………………………………………… ………………………………… …..……………
(Street address) *(Suburb)* *(Post code)*

hereby consent to be involved in the assessment of a study to be undertaken by Associate Professor Jo Salmon of the School of Exercise and Nutrition Sciences, Deakin University, to assess the effectiveness of a new school- and home-based program to reduce sedentary (sitting) time and increase physical activity and health in children.

I acknowledge that:

1. I have read and understand the attached Plain Language Statement. I freely agree to participate in this project. I have been given a copy of the Plain Language Statement to keep.
2. My participation involves:
   - The completion of surveys on four occasions to provide background information about myself (eg, age, level of education, etc), information about my child's sedentary and physical activity habits; and feedback regarding the program;
   - An invitation to participate in a 30-minute focus group/interview on four occasions to provide addition information about my child's sedentary and physical activity habits and feedback regarding the program;
   - Forwarding a plain language statement, consent form and one page question sheet to my child's other biological parent.
3. The researchers have agreed not to reveal my identity or any of my personal details, including where information about this project is published, or presented in any public form. My individual results will not be released to any person or organisation except at my request and on my authorisation.
4. Aggregated (summarised) results will be used for research purposes and may be reported in scientific and academic journals and conference meetings.
5. I am free to withdraw myself and/or my child from this study at any time and that any information obtained from my child or I up until that point will not be used and will be destroyed.

Participant's Signature ………..……………………………………………………………………….. Date …………………

DEAKIN UNIVERSITY
School of Exercise and Nutrition Sciences
Melbourne Campus
221 Burwood Highway
Burwood Victoria 3125 Australia
Telephone: 9244 6278 Facsimile: 9244 6017

ID: _______

Transform-Us! Consent form – Consent From on behalf of a minor - child participation

I, ……….. of
(*Please print parent/guardian's full name*)

………………………………………………………………………………… ………………………………………… ……………
(Street address) *(Suburb)* *(Post code)*

hereby give consent for my child ………………………………………………………………DOB…/……/……..
(Child's name) *(dd/mm/yyyy)*

to be involved in the following assessment component/s of a study to be undertaken by Associate Professor Jo Salmon of the School of Exercise and Nutrition Sciences, Deakin University ***(please tick the boxes to indicate which component/s you consent to):***

	YES	**NO**
Survey	☐	☐
Height, weight and waist circumference measurements	☐	☐
Blood pressure measurement (Term1/2 2010, Term 4 2011, Term 4 2012)	☐	☐
Wearing an activity monitor or 8 consecutive days	☐	☐
Wearing an activPAL for 8 consecutive days	☐	☐
Collection of a fasting blood sample (Term1/2 2010, Term 4 2011, Term 4 2012)	☐	☐
A tape-recorded focus group or one-one-one interview	☐	☐

Is there any Medical reason why blood should not be taken from your child (eg Haemophilllia, taking drugs that effect clotting)? ☐**NO** ☐**YES** Please explain:____

These assessments will take place on four separate occasions (three for blood pressure and blood sampling) in Term 1/2 2010, Term 4, 2010, Term 4 2011, and Term 4 2012, to evaluate the effectiveness of a new program to reduce the amount of time my child spends sedentary and to increase my child's physical activity.

I acknowledge that:

1. I have read and understand the attached Plain Language Statement. I freely agree to allow my child to participate in the trial. I have received a copy of the Plain Language Statement to keep.
2. The researchers have agreed not to reveal my child's identity and personal details, including where information about this project is published, or presented in any public form. My child's results will not be released to any person or organisation except at my request and on my authorisation.
3. Aggregated (summarised) results will be used for research purposes and may be reported in scientific and academic journals and conference meetings.
4. I am free to withdraw my child from this study at any time and that any information obtained from my child up until that point will not be used and will be destroyed.

Parent/Guardian's Signature ……………………………………………………… Date …………………………

<u>NOTE:</u> Only the parents or legal guardians of the child may provide consent for the child to participate. The parent(s)/guardian(s) of the child <u>must sign</u> the consent form in order for the child to participate.

21. Which of the following LEISURE activities does your child USUALLY do during a typical WEEK? (In the current school term, do NOT include school holidays)

During a typical WEEK what leisure activities does your child usually do?	Does your child usually do this activity?	TOTAL hours/minutes AFTER SCHOOL Mon-Fri	TOTAL hours/minutes WHOLE DAY Mon-Fri	TOTAL hours/minutes Saturday & Sunday
Example: TV	No$_1$ (Yes$_2$)	10 hours	15hrs	6hrs 45mins
a. TV / videos/DVD's	No$_1$ Yes$_2$	____Hrs____Mins	____Hrs____Mins	____Hrs____Mins
b. Playstation© / Nintendo© / computer games	No$_1$ Yes$_2$	____Hrs____Mins	____Hrs____Mins	____Hrs____Mins
c. Nintendo Wii	No$_1$ Yes$_2$	____Hrs____Mins	____Hrs____Mins	____Hrs____Mins
d. Computer / Internet (excluding games)	No$_1$ Yes$_2$	____Hrs____Mins	____Hrs____Mins	____Hrs____Mins

ABOUT YOU

47. What relation are you to the child involved in this study? (please tick *one* box)

☐1	Mother	☐2	Female carer
☐3	Father	☐4	Male carer
☐5	Grandparent	☐6	Guardian
☐7	Other (please state): ______________________		

48. Thinking about the child involved in this study, which of the following applies to their family situation? (please tick *one* box)

☐1 Both the child's birth parents live together
☐2 The child's birth parents live apart
☐3 Other family situation. Please describe: ______________________________

49. How old are you, the parent? ________ years

50. What is your sex? (please tick *one* box)

☐1 Male
☐2 Female

51. What is your current marital status? (please tick *one* box)

☐1	Married	☐4	Divorced
☐2	De facto/Living together	☐5	Widowed
☐3	Separated	☐6	Never married

52. Where were you born? (please tick *one* box)

☐1	Australia	☐6	Germany
☐2	UK or Ireland	☐7	New Zealand
☐3	Italy	☐8	Vietnam
☐4	Greece	☐9	Poland
☐5	Netherlands	☐10	Other (please state) _____________

53. In your household, do you <u>usually</u> speak English? (please tick *one* box)

☐1 Yes
☐2 No

54. What is your highest level of schooling? (please tick *one* box)

- ☐1 Never attended school
- ☐2 Primary school
- ☐3 Some high school
- ☐4 Completed high school
- ☐5 Technical or trade school certificate/apprenticeship
- ☐6 University or tertiary qualification

55. How tall are you without shoes? (If unsure please state your best guess)

___________cm **or** ______________feet/inches

56. How much do you weigh without clothes or shoes? (If unsure please state your best guess)

___________kg **or** ______________stone/pounds

57. How many children 'dependents' currently live in your house (including the child in this study)?

Write the number here: _______

Please list the age and gender of each child below: (please INCLUDE the child in this study)

	Age (years)	Gender (M/F)
1)	_________	_________
2)	_________	_________
3)	_________	_________
4)	_________	_________
5)	_________	_________
6)	_________	_________

58. Are you currently: (please tick *as many* as apply)

- ☐1 Employed full time in paid employment
- ☐2 A night-shift worker
- ☐3 Employed full time in unpaid employment
- ☐4 A shift worker
- ☐5 Employed part time in paid employment
- ☐6 Retired
- ☐7 Employed part time in unpaid employment
- ☐8 Unemployed
- ☐9 Home-duties full time
- ☐10 A student
- ☐11 Other (please state) ____________________________

59. Thinking about the last month, in a typical working week (Monday to Friday), on average, how many hours per day did you spend working in paid employment outside your home?

________ hours per day

YOUR CHILD'S DIET

32. In the past month, about how often has your child had the following? (Please tick *one* response on each line)

	Never or less than once /month$_1$	1-3 times/ month$_2$	Once/ week$_3$	2-4 times/ week$_4$	5-6 times/ week$_5$	Once a day$_6$	2-3 times a day$_7$	4-5 times a day$_8$	6 or more times a day$_9$
a. Potato crisps or salty snack foods	○	○	○	○	○	○	○	○	○
b. Chocolate or lollies	○	○	○	○	○	○	○	○	○
c. Cake, doughnuts, sweet biscuits	○	○	○	○	○	○	○	○	○
d. Pies, pasties or sausage rolls	○	○	○	○	○	○	○	○	○
e. Fast foods (e.g. McDonalds, KFC, Pizza)	○	○	○	○	○	○	○	○	○
f. Hot chips, French fries, wedges, or fried potatoes	○	○	○	○	○	○	○	○	○

33. About how many serves of vegetables does your child usually eat per day? Do not include hot chips or fried potato. (1 serve = ½ cup cooked vegetables or 1 cup salad vegetables) (Please tick one response only)

	My child does not eat Vegetables$_1$	Less than one serve/ day$_2$	One serve/ day$_3$	2 Serves/ day$_4$	3 Serves/ day$_5$	4 Serves/ day$_6$	5 Serves/ day$_7$	6 or more Serves/ day$_8$
Vegetables	○	○	○	○	○	○	○	○

34. About how many serves of fruit does your child usually eat per day? Do NOT include fruit juice. (1 serve = 1 medium piece or 2 small pieces of fruit or 1 cup of diced pieces) (Please tick one response only)

	My child does not eat fruit$_1$	Less than one serve/ day$_2$	One serve/ day$_3$	2 Serves/ day$_4$	3 Serves/ day$_5$	4 Serves/ day$_6$	5 Serves/ day$_7$	6 or more Serves/ day$_8$
Fruit	○	○	○	○	○	○	○	○

35. About how many serves of fruit juice does your child usually drink each day? (Please tick one response only) (1 serve = 125ml or ½ cup/glass or popper/tetra pack)

	My child does not drink fruit juice$_1$	**Less than one serve/ day$_2$**	**One serve/ day$_3$**	**2 Serves/ day$_4$**	**3 Serves/ day$_5$**	**4 Serves/ day$_6$**	**5 Serves/ day$_7$**	**6 or more Serves/ day$_8$**
Fruit juice	○	○	○	○	○	○	○	○

36. About how much SOFT DRINK (excluding diet soft drinks) does your child usually drink each day? (include all types of soft drink, including fruit flavoured drinks and sports drinks, but exclude any diet soft drinks, fruit juice or plain water) (Please tick one response only) (1 serve = 125ml or ½ cup/glass; 1 can = 3 serves; 600ml bottle = 5 serves; 1.25ml bottle = 10 serves)

	My child does not drink soft drinks$_1$	**Less than one serve/ day$_2$**	**One serve/ day$_3$**	**2 Serves/ day$_4$**	**3 Serves/ day$_5$**	**4 Serves/ day$_6$**	**5 Serves/ day$_7$**	**6 or more Serves/ day$_8$**
Soft Drinks	○	○	○	○	○	○	○	○

TRANSFORM-US!

INSTRUCTIONS FOR CHILD BLOOD SAMPLE

Dear ___________,

Thank you for agreeing for your child to have their blood sampled. This will provide us with valuable information about his/her diabetes and cardiovascular disease risk. In addition, you will also find out what blood type your child has.

Please find enclosed:

- A Melbourne Pathology Collection request form, and
- A brief survey

Please complete this survey on the morning of your child's blood sample and take it, with the collection request form, to any Melbourne Pathology Collection centre within the next week to have your child's blood sampled (a list of collection centres within 20kms of your child's school on the reverse of this letter). You do not need to make an appointment.

Please note: this is a <u>fasting blood sample</u>, therefore your child <u>must not have anything to eat or drink</u>, with the exception of water, for 8-15 hours prior to the sample being taken. Please ensure your child is well hydrated (water only) and refrain your child from exercising prior to the sample.

The blood sample must be taken in the next 7 days by:

If required, the Transform-Us! team can post out EMLA, a topical anaesthetic cream, to minimise the discomfort of your child. Please contact the team if you require this.

Once we received your results, we will give you a $20 voucher (eg Coles Myer) as compensation for your time.

The Transform-Us! General Practitioner is available on Tuesdays and Thursday mornings. If you have any questions about the sampling, please feel free to contact us (9244 6278 or email transform-us@deakin.edu.au) and the General Practitioner will then contact you to answer your queries.

Yours Sincerely,

The Transform-Us! Team

Appendix D: Lifestyle of our Kids (LOOK) study materials

D.1 School information and consent
D.2 Parent information and consent
D.3 LOOK 2009 family questionnaire
D.4 LOOK 2006 family questionnaire
D.5 Instructions for fasting blood sample

Appendix D.1 School information and consent

LOOK
Lifestyle Of Our Kids

Commonwealth Institute
AUSTRALIA

Dear <Principal> **July 20 2005**

I have the privilege of directing an internationally funded longitudinal research program on the relationship between Lifestyle and Health of our children (the LOOK project). The project has been approved by ACT Education and Training (see attached letter) and the Chief Minister, Jon Stanhope following supportive meetings with Katy Gallagher and Simon Corbell. It has also been approved by the Ethics Committee of the Australian Sports Commission.

The funding for this project emanates from the Commonwealth Institute, a body in London, the charter of which is to promote Education and Health in Commonwealth Countries. Activities of the Commonwealth Institute are signed off at CHOGM by our Federal Minister for Education. This project could have been set up anywhere in the Commonwealth and we are fortunate to have convinced the Commonwealth Institute that the ACT was a perfect place, due to the anticipated interest and reputation of our public primary school system and staff as well as the confined geographical nature of the ACT .

There will be approximately 25 ACT government primary schools involved and your school has been chosen as one that is considered most appropriate. The purpose of this letter is to briefly introduce you to this project after which I will phone to arrange a meeting with you to discuss your possible involvement.

The Project
A longitudinal project over four years where we monitor the health of children along with lifestyle factors, in particular physical activity and nutrition.

Children involved
Just one grade (i.e. school year) in each school is involved each year. This will be Grade 2 to begin and we follow these children through to Grade 6.

Features of the Project
LOOK is a multi-disciplinary project that monitors many aspects of health, specifically early symptoms of cardiovascular disease, type 2 diabetes, bone health, immuno-competence, psychological problems, as well as postural and coordination. Needless to say we have a variety of teams of researchers, all of whom have excellent national and international reputations. These include medical staff from The Canberra Hospital, ANU Medical Faculty, Royal Prince Alfred Hospital in Sydney and the International Diabetes Institute in Melbourne.

Starting time
Term 4 2005. The research team will come to the school for most of the tests, and two tests will be carried out at Canberra Hospital.

Address: PO Box 3798 Manuka ACT 2603 **Email**: rtelford@cominst.org.au **Phone:** 0411 237 908

Frequency and Duration of the Project:
Test periods in 2005, 2007 and 2009.

Time out of class
There is a visit to the Canberra Hospital taking two hours approximately. Most of the other major tests are done in physical education or other class time and estimated at around 4 hours (every two years).

What do we get out of it?
The classes involved will receive a comprehensive health assessment. This would not normally be done with children as the cost per child would be well over $1000 for the series of tests. Parents will receive comprehensive reports.

We intend to provide information to the class-room teachers to assist in using the experience as an educational tool for the children. For example, learning about bones, or the heart. Some of the schools will receive four years of physical education by a visiting specialist working with the class-room teacher and providing concurrent professional development. I would also like to discuss other ways we can make a contribution to participating schools and the children who participate in this project.

We as a community will gain a greater understanding of the links between health and lifestyle so that recommendations can be made to our politicians. Clearly, preventive medicine is required rather than reactive medicine to overcome problems of our medical system and crowded hospitals. A feature of this research is the investigation between lifestyle in childhood and disease in adulthood.

As mentioned above I will call to arrange a meeting with you provide you with more information and to seek your interest in this project. As you might imagine, the scope of this project is unique and we hope that it will make a significant impact on preventive medicine in the 21st century.

Yours sincerely

Dick Telford

Professor Richard D Telford AM PhD FACSM
Director, LOOK Project, Commonwealth Institute (UK and Australia)
Adjunct Professor, Faculty of Medicine, ANU
rtelford@cominst.org.au
PO BOX 3798
Manuka 2603

Appendix D.2 parent information and consent

LOOK Lifestyle Of Our Kids

Letter to Parents.

August 2005,

Dear Parent

Your school has been nominated to participate in a very important study of health and development in relation to lifestyle The program has been designed in conjunction with members of staff of the Faculty of Medicine, ANU, the Canberra Hospital, The Diabetes Institute (Melbourne), Royal Prince Alfred Hospital (Sydney) and Deakin University (Melbourne).

We believe that your child will benefit enormously from the comprehensive health reports you will receive each two years. Furthermore we plan to provide ongoing opportunity for comprehensive health checks to continue into adolescence and adulthood all free of charge.

There will be absolutely no costs to the school or to parents as the project is fully funded by the Commonwealth Institute. In fact half of all the schools (based on random selection) will receive free special physical education by visiting specialist physical education teachers every week at school for the whole of their primary school days.

We aim to make this a "fun" experience as well as an educational one as the class room teacher may incorporate the testing session into the curriculum (for example in learning about the heart or bone strength).

I have included information sheets on the project and website for the LOOK program www.look.org.au will also provide information on the nature of the tests which nicely complement the school health and physical education curriculum.

We do hope your child can participate in this project as we monitor the role of primary school education and lifestyle in your child..

Yours sincerely

Professor Richard (Dick) Telford AM
LOOK project Research Director, Commonwealth Institute
Adjunct Professor, Faculty of Medicine, Australian National University

Introduction to the Study.

What is the LOOK (Lifestyle of Our Kids) Study?

This is a longitudinal project with primary school children to study physical and psychological health over a four-year period from Grade 2 to Grade 6. Special attention will be applied to the relationship of health and development with physical activity. LOOK is fully privately funded by the Commonwealth Institute (Australia).

The Questions we want our research to answer

We have many questions, but our basic ones are:
(a) Can lifestyle choices, even those in primary school, affect the current health of our kids?
(b) Is it possible that lifestyle choices in the formative years can set the pattern for health throughout adulthood?
(c) Is provision of special movement education worth the effort with our growing children?

The Research Tests

Heart and Blood Vessel Health.
We have two non-invasive indicators of blood vessel and heart structure and function.

Bone health and development.
There are two scans for bone density and geometry (at The Canberra Hospital). The first is called a DXA scan, and is used in hospitals to investigate bone fragility and osteoporosis. The second is called a peripheral QCT scan, and involves scans of the arm and the leg. No ill-effects of these scans have ever been reported and these standard techniques have already met Ethics Committee approval at the Australian Sports Commission.

Blood Health Indicators.
One venous blood sample is to be taken every two years for indication of risk of cardiovascular disease and type 2 diabetes. This procedure will be carried out at school. Highly experienced technical staff and nurses will take the blood sample from the arm, any discomfort being significantly minimized with the use of local anaesthetic "rub on" patch applied 20 minutes before the test. Because the children are not to have had breakfast before this test, we will provide breakfast at school.

Measuring Physical Activity.
A pedometer is a device that counts the number of steps we take. The children will be provided with a pedometer and instructions and asked to wear the pedometer for 5 days at home and school.

Measuring Physical Performance.
There are two simple performance tests, a vertical jump test and a shuttle run or "beep test". The latter involves running between two markers 20m apart so as to arrive at the marker before the recorded "beep". This test will be carried out in the physical education class

Balance and coordination.
A group of balance and coordination tests, aimed at measuring posture during movement. Carried out in physical education classes.

Psychological measures.
A questionnaire (to children) to assess psychological components of health and development (including self-esteem, anxiety, self-image) and family influences on physical activity. Done in class, and a questionnaire for parents.

Nutritional Intake.
A diet diary will be provided (to parents) to assess nutritional intake. There may be an interview with parent and child to help with the questionnaire on food intake.

Duty of Care
Any child found with a measure suggesting immediate medical attention will be advised in a letter to the school or their parents as required, as part of the health report.

The major test periods
The major testing periods are in Terms 4 of year 2005, 2007, and 2009. In most cases tests will be administered to small groups of children at a time, at the school. Occasionally the whole class will be involved as part of their physical education class

For further information visit: www.look.org.au
or
phone: (02) 61 611 653

LOOK
Lifestyle Of Our Kids

Frequently Asked Questions.

Q - What are the main benefits of my child participating?

- Your child will receive a free comprehensive health check up every two years from Year 2 to Year 6.
- Parents will get confidential reports on the results of all the assessments. All reports will be in plain English.
- Half of the selected schools will receive free special movement education classes.

Q - What if we change our mind and don't want to participate?

Parents can withdraw their children from the study at any time they choose.

Q - Can parents attend any of the testing sessions?

Parents are encouraged to attend all of the testing sessions if they are in a position to do so as we would love to have them involved with the ongoing stages of the study.

Q - How many tests are outside the school?

There is only one excursion outside the school. This is to the Canberra Hospital where an ultrasound picture of the heart, blood pressure, and measurement of bone strength by a scanning technique will take place. Parents are encouraged to attend this session, and take their child if they have time. We will not assume this of course and have a driver taking small groups of children for each session. The time at the hospital will be two hours approximately.

Q - My child is worried about the blood test. Is this usual?

Yes, most of us find blood being taken a little daunting. However our experienced nurses are using a small anaesthetic patch applied to the skin and this takes away most if not all of any sting. Unfortunately to obtain comprehensive health information we can't avoid the blood test every two years. Each child will receive a small token of our appreciation for "being brave" and recieve breakfast after the test with the class.

Q - What is the procedure if one of the results requires medical follow-up?

The parents will be notified personally by phone and mail, with notification of the result in question and the recommended follow-up procedure (which would normally be to consult the family doctor with the test result).

Q - Will my child enjoy the project?

We are certainly going out of our way to make sure this is the case. No child will ever be put in a potentially embarrassing or unenjoyable situation. We blieve all our tests, for example wearing a pedometer will be both enjoyable and educational.

Q - Will my child miss many classes?

No, because only a small group of children will be doing the tests at any one time, waiting time will be minimal. Of importance to the testing team is that the results of the test will be learning opportunities for the children.
For example, the results of the heart function can be used by the class-room teacher to develop a lesson around the role of the heart.

For further information visit: www.look.org.au

or

phone: (02) 61 611 653

Parent Consent Form.

PARENTAL CONSENT FORM

Lifestyle of our Kids (LOOK)

A study of the relationship between lifestyle and health of our children.

This is to certify that I, _________________________________ hereby agree to give permission to have my child participate as a volunteer in this health-related research project.

I understand the nature of the tests and what they measure and that the tests will be conducted every two years in primary school. It has been explained to me that there will be one invasive test, a blood sample taken from an arm vein by experienced nurses and technicians, following an application of an anaesthetic patch. The benefits of this test in detecting early signs of diabetes or cardiovascular disease are considered to outweigh any slight discomfort.

- I have been given an opportunity to ask whatever questions all such questions and inquiries have been answered to my satisfaction.
- I understand that I am free to deny any answers to specific items or questions in interviews or questionnaires.
- I understand that I and my child are free to withdraw consent and to discontinue participation in the project or activity at any time.
- I understand that any data or answers to questions will remain confidential with regard to my and my child's identity.
- I certify to the best of my knowledge and belief, that my child has no physical or mental illness or weakness that would form a risk of (him/her) participating in this investigation.
- My child is participating in this project of (his/her) own free will and we have not been coerced in any way to participate.

Signature of Parent or
Guardian of minor: (under 16 years)

____

Date: ___/___/___

For further information
visit: www.look.org.au
or
phone: (02) 61 611 653

Appendix D.3 LOOK 2009 family questionnaire

Family Questionnaire 2009

This Family Questionnaire has been designed to learn more about the health of families and children who participate in the LOOK project.

It is important to our study that a parent or guardian completes this Questionnaire.

Please be assured that all answers will be kept strictly confidential.

After completing this Questionnaire please return it to your child's school Front Office in the envelope provided

START HERE:

Your child's name: ______________________ ______________________
(first name) (last name)

Which High School will your child be attending in 2010? ______________________

What suburb do you live in? ______________________ Post Code: ______________

How long have you lived in your local area? __________ years

Please fill in your contact details below so we can send you future reports, research findings and correspondance for further research. Your details will only be used by the LOOK Study.

Your Name: ______________________

Address: ______________________

Email: ______________________

Phone: ______________________

SECTION 1: The Family

The following questions will help us to find out more about the parents of children in the LOOK Project.

(Please tick appropriate box)

1. Are you: ❑ Male ❑ Female

2. What is your age in years? ____________

3. What is your Spouse/ Partners age in years?

____

4. What is your main occupation?

Self ______________

Spouse/Partner ______________

5. Which of the following best describes YOUR current employment and that of your partner? (tick one box)

Self

- ❑ Full time
- ❑ Part time
- ❑ Pensioner
- ❑ Home duties
- ❑ Other__________

Spouse/Partner

- ❑ Full time
- ❑ Part time
- ❑ Pensioner
- ❑ Home duties
- ❑ Other __________

6. Which of the following best describes your current marital status?

- ❑ Single/Never married
- ❑ Married
- ❑ Defacto/partner
- ❑ Separated/Divorced
- ❑ Spouse deceased

7. How many children are in the family? (tick one box)

❑ 1 child ❑ 2 children ❑ 3 children
❑ 4 children ❑ 5 children or more

8. Which of the following best describes your relationship to this child?

- ❑ Biological parent
- ❑ Step parent
- ❑ Guardian/ Foster parent
- ❑ Adoptive parent
- ❑ Other __________________

9. Who does your child usually live with? (tick MORE than one box if appropriate)

- ❑ Both parents
- ❑ Parent/s and grandparent/s
- ❑ Mother alone
- ❑ Brother/s
- ❑ Father alone
- ❑ Sister/s
- ❑ Stepbrother/s
- ❑ Stepsisters/s
- ❑ Grandparent/s
- ❑ Mother and Stepfather
- ❑ Father and Stepmother
- ❑ Shared care between separated mother and father
- ❑ Other __________________

10. Are you concerned about your child's weight?

❑ Yes ❑ No

If yes, what are your concerns?

____

11. Are you concerned about your child's height?

❑ Yes ❑ No

If yes, what are your concerns?

____

12. Does the child's mother / female guardian smoke?

❑ Yes ❑ No

13. Does the child's father / male guardian smoke?

❑ Yes ❑ No

14. What is the height of the child's biological mother?

_________ metres OR ________ feet/inches

OR non-biological mother/ guardian

_________ metres OR ________feet/inches

15. What is the weight of the child's biological mother?

______ kilograms OR ______ stones/pounds

OR non-biological mother/ guardian

______ kilograms OR ______ stones/pounds

16. What is the height of the child's biological father?

_________ metres OR ________ feet/inches

OR non-biological father/ guardian

_________ metres OR ________feet/inches

17. What is the weight of the child's biolgical father?

______ kilograms OR ______ stones/pounds

OR non-biological father/ guardian

______ kilograms OR ______ stones/pounds

18. How would you decribe your own physical activity level on most days?

Mother / female Guardian:

❑ Not active at all on most days

❑ Light activity, e.g housework, office work, standing on most days

❑ Moderately active, e.g cleaning, walking on most days, some sport or activity

❑ Very active, e.g. physical work, play sport, quite active on most days

Father / male Guardian:

❑ Not active at all on most days

❑ Light activity, e.g housework, office work, standing on most days

❑ Moderately active, e.g cleaning, walking on most days, some sport or activity

❑ Very active, e.g. physical work, play sport, quite active on most days

19. How would you describe your child's physical activity level on most days?

❑ Not active at all on most days

❑ Light activity

❑ Moderately active

❑ Very active

20. Is there a history of osteoporosis (e.g. thin or brittle bones in the family ?

❑ Yes ❑ No ❑ Don't know

21. Has your son/daughter taken any medication in the past for long period of time (greater than 6 months) e.g medication for epilepsy, asthma or calcium supplements...?

❑ Yes ❑ No

If Yes, please complete the following table:

At what age did your child begin taking the medicatioin?	For how many years did your child take it?	Name of the medication	Purpose of the medication (e.g asthma)	Is your child still taking it? (Yes/ No)

22. Has your son/daughter ever fractured a bone?

❑ Yes ❑ No

If Yes, please complete the following table: (please list ALL fractures)

Age of your child when the fracture occured	Site of Fracture (e.g right wrist, left leg....	Cause of the fracture (e.g fall from bike)

23. How does your child normally get to school?

❑ car ❑ bus

❑ walks ❑ cycles

❑ other________________________________

24. How frequently in the last month have you ....

	none	1 - 2 days	3 - 4 days	5 - 6 days	daily
Provided transport for your child to do physical activity or sport	❑	❑	❑	❑	❑
Watched your child being physically active or playing sport	❑	❑	❑	❑	❑
Talked about the benefits of doing physical activity or sport	❑	❑	❑	❑	❑
Supported any other children to be physically active or play sport	❑	❑	❑	❑	❑

25. How important to you is it for your child to participate in physical activity and/or sport outside of school?

❑ unimportant ❑ important
❑ very important

26. How important is it to you that YOU set time aside for regular physical activity for yourself?

❑ unimportant ❑ important
❑ very important

27. Family rules: Some families apply rules that limit TV or video games. How true is this for your family?

❑ not true ❑ true
❑ unsure

28. On a school day, how many hours of television, computers or electronic games does your child watch?

❑ zero ❑ 2 to 3 hours
❑ less than two hours ❑ 4 hours or more

29. How many computers and televisions are in your house?

❑ zero ❑ 2 to 3
❑ 1 ❑ 4 or more

30. Does your child have a computer/television in his/her room?

❑ Yes ❑ No

31. How many evenings does your family usually eat dinner together?

❑ zero ❑ 5 to 6 times
❑ 1 to 2 times ❑ Every night
❑ 3 to 4 times

32. How many evenings does your family usually eat dinner watching television?

❑ zero ❑ 5 to 6 times
❑ 1 to 2 times ❑ Every night
❑ 3 to 4 times

33. On an average school day, what time does your child go to bed? ______ pm

34. On an average school day, what time does your child get up in the morning? ______ am

35. Does your child snore?

❑ Yes ❑ No

36. Does your child wake in the morning feeling refreshed?

❑ Yes ❑ No

37. Does your child fall asleep during the day?

❑ rarely ❑ often
❑ occassionaly ❑ regularly

38. School attendance: During the last school term how many days of school did your child miss?

- ❑ 0 days
- ❑ 6 to 10 days
- ❑ 1 to 5 days
- ❑ more than 10 days

39. Was your child's absence from school mainly due to:

- ❑ Medical Reasons
- ❑ Family Reasons
- ❑ Something else

40. In a normal week how many times does your child eat a take away/fast food dinner?

- ❑ never
- ❑ twice
- ❑ once
- ❑ 3 or more

41. In a normal week, how many times does your child eat breakfast?

- ❑ never
- ❑ 4 to 6 days
- ❑ 1 to 3 days
- ❑ daily

42. On average, how many glasses of soft drink does your child drink in one week? (1 can is about 2 glasses)

- ❑ none
- ❑ 4 to 7 glasses
- ❑ 1 to 3 glasses
- ❑ more than 7

43. On average, how many glasses of sweetened drinks (eg juice, sports drinks or cordial) would your child drink in one week?

- ❑ none
- ❑ 4 to 7 glasses
- ❑ 1 to 3 glasses
- ❑ more than 7

44. Who usually decides the type of snack your child has after school?

- ❑ He/she selects his/her own
- ❑ A parent/ grandparent or other relative
- ❑ After School Carer
- ❑ Other______________

45. Who usually decides when your child has had enough to eat?

- ❑ He/she makes own decision
- ❑ A parent/ grandparent or other relative
- ❑ After School Carer
- ❑ Other______________

46. How many pieces of fruit did your child eat yesterday? *(a handful of grapes = 1 piece of fruit)*

- ❑ none
- ❑ 1
- ❑ more than 1

47. How many serves of vegetables did your child eat yesterday? *(a serve = one standard cup)*

- ❑ none
- ❑ 1
- ❑ more than 1

48. How many serves of dairy foods does your child usually eat per day? *(a serve depends on the type of dairy product. For example a serve of diary can equal one standard glass of milk, one small tube of yoghurt, or one slice of cheese)*

- ❑ none
- ❑ 1
- ❑ more than 1

49. How many standard glasses of water would your child have each day?

- ❑ none
- ❑ 1
- ❑ more than 1

SECTION TWO: YOUR CHILD'S RECENT PHYSICAL ACTIVITY

1. List the main physical activities that have happened over the past week OR are likely to occur in the next two weeks (that are representative of a typical week).
Please list the type of activity (Organised, Unorganised or both), where the activity took place, who the activity was done with and how long the activity went for.

Examples of Organised activities are: team sports, swim squad, dance, football training, dance lessons,
Examples of Unorganised activities are: free play, walking, cycling, swimming for fun, trampoline

DAY	**Activity after school & weekends** (eg organised physical activity = dance, swim lessons / squad and unorganised physical activity = free play, walking, cycling, swimming for fun	**How long the activity went for** (in minutes)	**Who the activity was with?**
MONDAY	**Organised physical activity** ❑ Yes ❑ No If 'yes' what type of activity?__________	______ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family
	UnOrganised physical activity ❑ Yes ❑ No If 'yes' what type of activity?__________	______ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family
TUESDAY	**Organised physical activity** ❑ Yes ❑ No If 'yes' what type of activity?__________	______ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family
	UnOrganised physical activity ❑ Yes ❑ No If 'yes' what type of activity?__________	______ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family
WEDNESDAY	**Organised physical activity** ❑ Yes ❑ No If 'yes' what type of activity?__________	______ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family
	UnOrganised physical activity ❑ Yes ❑ No If 'yes' what type of activity?__________	______ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family
THURSDAY	**Organised physical activity** ❑ Yes ❑ No If 'yes' what type of activity?__________	______ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family
	UnOrganised physical activity ❑ Yes ❑ No If 'yes' what type of activity?__________	______ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family
FRIDAY	**Organised physical activity** ❑ Yes ❑ No If 'yes' what type of activity?__________	______ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family
	UnOrganised physical activity ❑ Yes ❑ No If 'yes' what type of activity?__________	______ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family

DAY	Activity after school & weekends (eg organised physical activity = dance, swim lessons / squad and unorganised physical activity = free play, walking, cycling, swimming for fun	How long the activity went for (in minutes)	Who the activity was with?
SATURDAY	**Organised** physical activity ❑ Yes ❑ No If 'yes' what type of activity? ________	______ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family
	UnOrganised physical activity ❑ Yes ❑ No If 'yes' what type of activity? ________	______ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family
SUNDAY	**Organised** physical activity ❑ Yes ❑ No If 'yes' what type of activity? ________	______ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family
	UnOrganised physical activity ❑ Yes ❑ No If 'yes' what type of activity? ________	______ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family

2. Is this pattern normal for your child? ❑ Yes ❑ No
If NOT please explain ______________________________

3. In the last year has your child belonged to a sporting club? ❑ Yes ❑ No
If YES, which one/s? ______________________________

4. Who usually decides what activity your child does after school?

❑ He/she selects own activity
❑ A parent/ grandparent or other relative
❑ After School Carer
❑ Other______________

5. It is not always possible to allow children to be physically active and do what they would like to do after school. Which of the following **prevents** your child from doing the activities he/she would like to do after school? Rank for your child from 1- 13.

1= Most of often stops my child from being active after school. 13= Least often stops my child from being active

Reasons that prevents physical activity	Rank 1 - 13
My child doesn't like to do physical activity or play after school	
Lack of adult supervision	
Concerns about neighbourhood safety	
Poor weather	
No-one to play with	
High cost of classes or venues	
Lack of transport	
Lack of time for you to support or supervise activities	
No places to play	
Poor health in the past 6 months	
Chronic illness	
My child has no problems doing what he or she would like after school	
Other (please specify)	

THE END. Thankyou!

Thankyou for taking the time to complete this survey.
Any questions about the LOOK Study can be directed to:

The LOOK Study
Commonwealth Institute (Australia)
PO Box 3798 Manuka ACT 2603
Ph: 02) 61611653
Email: info@look.org.au
Web: www.look.org.au

Appendix D.4 LOOK 2006 family questionnaire

Family Questionnaire

This Family Questionnaire has been designed to learn more about the health of families and children who participate in the LOOK project.

It is extremely important to our project that a parent or guardian completes this questionnaire and returns it to your child's classroom teacher.

Please be assured that all answers will be kept strictly confidential.

If English is your second language and/or you require help to complete any questions please phone 61611653 for assistance.

START HERE

What is your child's name? ____________________ (first name) ____________________ (last name)

What school does he or she attend? ______________________________

What is your child's date of birth? ____ / ____ / ______ (Day / Month / Year)

Is your child male or female? (please tick) ☐ Male ☐ Female

What suburb do you live in? ____________________ Postcode: ____________

How long have you lived in your local area? ____________ years

SECTION 1:

The following questions will help us to find out more about the parents of children in the LOOK Project.

(Please tick the box that represents you, your family or your feelings)

1. Are you: ❑ Male ❑ Female

2. Age category:

Self	Spouse/Partner
❑ 20 - 29 years	❑ 20 - 29 years
❑ 30 - 39 years	❑ 30 - 39 years
❑ 40 - 49 years	❑ 40 - 49 years
❑ 50 - 59 years	❑ 50 - 59 years
❑ 60 - 69 years	❑ 60 - 69 years
❑ 70 + years	❑ 70 + years

3.What is your main occupation?

Self	Spouse/Partner
________________	________________

4. Which of the following best describes YOUR current employment and that of your partner? (tick one box)

Self	Spouse/Partner
❑ Full time	❑ Full time
❑ Part time	❑ Part time
❑ Pensioner	❑ Pensioner
❑ Home duties	❑ Home duties
❑ Other___________	❑ Other ___________

5. Which of the following best describes your current marital status?

❑ Single/Never married
❑ Married
❑ Defacto/partner
❑ Separated/Divorced
❑ Spouse deceased

6. What is your highest level of education completed?

Self	Spouse/Partner
❑ Year 10 or below	❑ Year 10 or below
❑ Year 11/12	❑ Year 11/12
❑ TAFE or trade qualification	❑ TAFE or trade qualification
❑ Tertiary degree	❑ Tertiary degree
❑ Other _________	❑ Other _________

7. What is the country of birth of the ..?

Child's biological MOTHER	Child's biological FATHER
❑ Australia	❑ Australia
❑ Other country (please name) ______________	❑ Other country (please name) ______________
❑ Don't know	❑ Don't know

8. What country was your child born in?

❑ Australia
❑ Other country (please name)
____
❑ Don't know

9. What is the origin of your .....?

Origin/ethnicity	Mother	Father	Grand-mother	Grand-father
Anglo Saxon	❑	❑	❑	❑
Aboriginal but not Torres Strait Islander	❑	❑	❑	❑
Torres Strait Islander but not Aboriginal	❑	❑	❑	❑
Aboriginal and Torres Strait Islander	❑	❑	❑	❑
Not Aboriginal or Torres Strait Islander	❑	❑	❑	❑
Polynesian - Maori/Tongan/Samoan	❑	❑	❑	❑
Indian / Sri Lankan / Pakistani / Afghani	❑	❑	❑	❑
South East Asian	❑	❑	❑	❑
Other ethnic origin	❑	❑	❑	❑
Don't know	❑	❑	❑	❑

The following questions refer to YOUR CHILD who participates in the "LOOK" study.

10. Which of the following best describes your relationship to this child?

- ❑ Biological parent
- ❑ Step parent
- ❑ Guardian/ Foster parent
- ❑ Adoptive parent
- ❑ Other ____________________

11. Who does your child usually live with?
(tick MORE than one box if appropriate)

- ❑ Both parents
- ❑ Parent/s and grandparent/s
- ❑ Mother alone
- ❑ Brother/s
- ❑ Father alone
- ❑ Sister/s
- ❑ Stepbrother/s
- ❑ Stepsisters/s
- ❑ Grandparent/s
- ❑ Mother and Stepfather
- ❑ Father and Stepmother
- ❑ Shared care between separated mother and father
- ❑ Other ____________________

12. This child is the ___ (tick one box) number in the family?

- ❑ 1st child
- ❑ 2nd child
- ❑ 3rd child
- ❑ 4th child
- ❑ 5th child or more

13. How many children are in the family altogether? (tick one box)

- ❑ 1 child
- ❑ 2 children
- ❑ 3 children
- ❑ 4 children
- ❑ 5 children or more

14. Are you concerned about your child's height?

❑ Yes ❑ No

If yes, what are your concerns?

____

15. Are you concerned about your child's weight?

❑ Yes ❑ No

If yes, what are your concerns?

____

16(a) Do you have a member of your family diagnosed with diabetes?

❑ Yes ❑ No

(b) If YES what is this person's relationship to your child?
(you can tick more than one if appropriate)

	❑ Father	❑ Mother	❑ Uncle/ aunt	❑ Grand-parent	❑ Other (explain) ______
What type of diabetes?	❑ Type 1 ❑ Type 2	❑ Type 1 ❑ Type 2	❑ Type 1 ❑ Type 2	❑ Type 1 ❑ Type 2	❑ Type 1 ❑ Type 2

(c) Did the child's mother have diabetes during any pregnancy/ies?

❑ Yes ❑ No

17. Approximately, what is the weight and height of the child's biological mother and father?

Child's MOTHER		Unable to say
Weight	__________ (kg)	❑
Height	__________(cm)	❑

Child's FATHER		Unable to say
Weight	__________ (kg)	❑
Height	__________(cm)	❑

18. Do the parents or grandparents of this child have a history of any of the following conditions?

Condition	Mother	Father	Grand mother	Grand father	Brother	Sister
	yes	yes	yes	yes	yes	yes
High blood pressure	❑	❑	❑	❑	❑	❑
High cholesterol	❑	❑	❑	❑	❑	❑
Heart disease	❑	❑	❑	❑	❑	❑
Stroke	❑	❑	❑	❑	❑	❑
Liver problems	❑	❑	❑	❑	❑	❑
Sleep apnoea	❑	❑	❑	❑	❑	❑

If there is someone or some people in your family with high blood pressure,

- can you please tell us the age the high blood pressure was first diagnosed?

____

- if known the cause of the high blood pressure

____

- if known the treatment of the high blood pressure

____

19. Does anyone in your family suffer from fragile bones?

❑ Yes ❑ No

<u>If YES</u>, was it diagnosed as osteoporosis?

❑ Yes ❑ No ❑ Other diagnosis

If other please specify ______________________

If YES, is the cause known?

____

20. Were any of the following conditions present during the pregnancy of the "LOOK" child?

	YES	NO
High blood pressure?	❑	❑
Premature labour*	❑	❑
Bleeding	❑	❑

Any other illness /treatment during this pregnancy?

____

*** If premature delivery occurred was a steroid injection given to help mature the baby's lungs?**

❑ Yes ❑ No

21. The following questions ask about the first records kept by the parent/s of this child.

How many week's did this pregnancy go for?	_______ weeks
What was the birth weight? (from hospital record or blue book)	_____ kilograms
What was the birth length?	_____ centimetres
What was the weight of this child at about 12 months of age?	_____ kilograms
For how long was this child breast fed?	_______ months
What age did this child commence bottle feeding?	_______ months
At what age did this child begin eating solids?	________ months

SECTION TWO: FAMILY HABITS

1. How frequently in the last month have you ....

	none	1 - 2 days	3 - 4 days	5 - 6 days	daily
Provided transport for your child to do physical activity or sport	❑	❑	❑	❑	❑
Watched your child being physically active or playing sport	❑	❑	❑	❑	❑
Talked about the benefits of doing physical activity or sport	❑	❑	❑	❑	❑
Supported any other children to be physically active or play sport	❑	❑	❑	❑	❑

2. How important to you is it for your child to participate in physical activity and/or sport outside of school?

❑ very unimportant
❑ unimportant
❑ neither important nor unimportant
❑ important
❑ very important

3. How important is it to you that YOU set time aside for regular physical activity for yourself?

❑ very unimportant
❑ unimportant
❑ neither important nor unimportant
❑ important
❑ very important

4. Family rules: Some families apply rules that limit TV or video games. How true is this for your family?

❑ very true
❑ true
❑ not sure
❑ Not true
❑ Not true at all

5. On a school day, how many hours of television, computers or electronic games does your child watch?

❑ zero
❑ less than two hours
❑ 2 to 3 hours
❑ 4 hours or more

6. How many computers and televisions are in your house?

❑ zero
❑ 1
❑ 2 to 3
❑ 4 or more

7. Does your child have a computer/television in his/her room?

❑ Yes ❑ No

8. How many evenings does your family usually eat dinner together?

❑ zero
❑ 1 to 2 times
❑ 3 to 4 times
❑ 5 to 6 times
❑ Every night

9. How many evenings does your family usually eat dinner watching television?

❑ zero
❑ 1 to 2 times
❑ 3 to 4 times
❑ 5 to 6 times
❑ Every night

10. On an average school day, what time does your child go to bed? ______ pm

11. On an average school day, what time does your child get up in the morning? _____ am

12. Does your child snore?

❑ Yes ❑ No

13. Does your child wake in the morning feeling refreshed?

❑ Yes ❑ No

14. Does your child fall asleep during the day?

❑ rarely
❑ occassionaly
❑ often
❑ regularly

15. School attendance: During the last school term how many days of school did your child miss?

- ❑ 0 days
- ❑ 6 to 10 days
- ❑ 1 to 5 days
- ❑ more than 10 days

16. Was your child's absence from school mainly due to:

- ❑ Medical Reasons
- ❑ Family Reasons
- ❑ Something else

17. In a normal week how many times does your child eat a take away/fast food dinner?

- ❑ never
- ❑ twice
- ❑ once
- ❑ 3 or more

18. In a normal week, how many times does your child eat breakfast?

- ❑ never
- ❑ 4 to 6 days
- ❑ 1 to 3 days
- ❑ daily

19. On average, how many glasses of soft drink does your child drink in one week? (1 can is about 2 glasses)

- ❑ none
- ❑ 4 to 7 glasses
- ❑ 1 to 3 glasses
- ❑ more than 7

20. On average, how many glasses of sweetened drinks (eg juice, sports drinks or cordial) would your child drink in one week?

- ❑ none
- ❑ 4 to 7 glasses
- ❑ 1 to 3 glasses
- ❑ more than 7

21. Who usually decides the type of snack your child has after school?

- ❑ He/she selects his/her own
- ❑ A parent/ grandparent or other relative
- ❑ After School Carer
- ❑ Other______________

22. Who usually decides when your child has had enough to eat?

- ❑ He/she makes own decision
- ❑ A parent/ grandparent or other relative
- ❑ After School Carer
- ❑ Other______________

23. How many pieces of fruit did your child eat yesterday? *(a handful of grapes = 1 piece of fruit)*

- ❑ none
- ❑ 1
- ❑ more than 1

24. How many serves of vegetables did your child eat yesterday? *(a serve = one standard cup)*

- ❑ none
- ❑ 1
- ❑ more than 1

25. How many serves of dairy foods does your child usually eat per day? *(a serve depends on the type of dairy product. For example a serve of diary can equal one standard glass of milk, one small tube of yoghurt, or one slice of cheese)*

- ❑ none
- ❑ 1
- ❑ more than 1

26. How many standard glasses of water would your child have each day?

- ❑ none
- ❑ 1
- ❑ more than 1

SECTION THREE: YOUR CHILD'S RECENT PHYSICAL ACTIVITY

1. List the main activities that have happened over the past week OR are likely to start happening in the next two weeks (that are representative of a typical week).
Please list the type of activity (Organised, Unorganised or both), where the activity took place, who the activity was done with, how long the activity went for and any costs involved.

Examples of Organised activities are: team sports, swim squad, dance, football training, dance lessons,
Examples of Unorganised activities are: free play, walking, cycling, swimming for fun, trampoline

DAY	**Activity after school & weekends** (eg organised physical activity = dance, swim lessons / squad and unorganised physical activity = free play, walking, cycling, swimming for fun	**How long the activity went for** (in minutes)	**Who the activity was with?**	**Where the activity happened**	**Any costs that had to be paid for the activity session**
MONDAY	**Organised physical activity** ❑ Yes ❑ No If 'yes' what type of activity? ________	________ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family	❑ Indoor ❑ Outdoor	$________ per session
	UnOrganised physical activity ❑ Yes ❑ No If 'yes' what type of activity? ________	________ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family	❑ Indoor ❑ Outdoor	$________ per session
TUESDAY	**Organised physical activity** ❑ Yes ❑ No If 'yes' what type of activity? ________	________ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family	❑ Indoor ❑ Outdoor	$________ per session
	UnOrganised physical activity ❑ Yes ❑ No If 'yes' what type of activity? ________	________ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family	❑ Indoor ❑ Outdoor	$________ per session
WEDNESDAY	**Organised physical activity** ❑ Yes ❑ No If 'yes' what type of activity? ________	________ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family	❑ Indoor ❑ Outdoor	$________ per session
	UnOrganised physical activity ❑ Yes ❑ No If 'yes' what type of activity? ________	________ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family	❑ Indoor ❑ Outdoor	$________ per session
THURSDAY	**Organised physical activity** ❑ Yes ❑ No If 'yes' what type of activity? ________	________ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family	❑ Indoor ❑ Outdoor	$________ per session
	UnOrganised physical activity ❑ Yes ❑ No If 'yes' what type of activity? ________	________ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family	❑ Indoor ❑ Outdoor	$________ per session
FRIDAY	**Organised physical activity** ❑ Yes ❑ No If 'yes' what type of activity? ________	________ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family	❑ Indoor ❑ Outdoor	$________ per session
	UnOrganised physical activity ❑ Yes ❑ No If 'yes' what type of activity? ________	________ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family	❑ Indoor ❑ Outdoor	$________ per session

DAY	**Activity after school & weekends** (eg organised physical activity = dance, swim lessons / squad and unorganised physical activity = free play, walking, cycling, swimming for fun	**How long the activity went for** (in minutes)	**Who the activity was with?**	**Where the activity happened**	**Any costs that had to be paid for the activity session**
SATURDAY	**Organised physical activity** ❑ Yes ❑ No If 'yes' what type of activity? ________	________ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family	❑ Indoor ❑ Outdoor	$________ per session
	UnOrganised physical activity ❑ Yes ❑ No If 'yes' what type of activity? ________	________ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family	❑ Indoor ❑ Outdoor	$________ per session
SUNDAY	**Organised physical activity** ❑ Yes ❑ No If 'yes' what type of activity? ________	________ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family	❑ Indoor ❑ Outdoor	$________ per session
	UnOrganised physical activity ❑ Yes ❑ No If 'yes' what type of activity? ________	________ minutes	❑ Friend ❑ Brother/sister ❑ Self ❑ Family	❑ Indoor ❑ Outdoor	$________ per session

2. Is this pattern normal for your child? ❑ Yes ❑ No
If NOT please explain ________________________________

3. In the last year has your child belonged to a sporting club? ❑ Yes ❑ No
If YES, which one/s? ________________________________

4. Who usually decides what activity your child does after school?

❑ He/she selects own activity
❑ A parent/ grandparent or other relative
❑ After School Carer
❑ Other____________

5. It is not always possible to allow children to be physically active and do what they would like to do after school. Which of the following prevents your child from doing the activities he/she would like to do after school? Rank for your child from 1- 13.

1= Most of often stops my child from being active after school. 13= Least often stops my child from being active

Reasons that prevents physical activity	Rank 1 - 13
My child doesn't like to do physical activity or play after school	
Lack of adult supervision	
Concerns about neighbourhood safety	
Poor weather	
No-one to play with	
High cost of classes or venues	
Lack of transport	
Lack of time for you to support or supervise activities	
No places to play	
Poor health in the past 6 months	
Chronic illness	
My child has no problems doing what he or she would like after school	
Other (please specify)	

END. Thankyou!

Thankyou for taking the time to complete this survey.
Any questions about the LOOK Study can be directed to:

The LOOK Study
Commonwealth Institute (Australia)
PO Box 3798 Manuka ACT 2603
Ph: 02) 61611653
Email: info@look.org.au
Web: www.look.org.au

Appendix D.5 Instructions for fasting blood sample

LOOK Lifestyle Of Our Kids

Blood Test

Dear Parent/ Guardian,

The final Blood test for the Primary school LOOK children is coming up. The blood test screens for Type 2 Diabetes, Heart Disease and other blood markers. As always you will be contacted if any abnormalities are detected.

We thank you for your continued involvement in this important study of children's health!

WHEN: <INSERT DATE> - 8.00am at school

PREPARATION

- no breakfast before the test (eating food before the test may give misleading results)
- drink a glass of water (dehydration leads to misleading results).
- no strenuous exercise before the test (physical activity leads to misleading results)

BREAKFAST WILL BE PROVIDED AFTER THE TEST

If you have any queries or concerns or are unable to attend the Blood Test please phone Rohan Telford on ph:61611653.

LOOK (Lifestyle Of Our Kids)
Address: PO Box 3798 Manuka ACT 2603 **Email**: rohan@look.org.au **Website:** www.look.org.au
Phone: (02) 61611653 **Fax:** (02) 61617929

APPENDIX E: Data tables

E.1 ActiGraph daily patterns of sedentary time

E.2 *activ*PAL™ daily patterns of sitting time

E.3 Interactions between sedentary variables and health outcomes according to age

Percentage of time spent sedentary during weekday and weekend day time periods in boys and girls

	Weekday			Weekend day		
	Boys	**Girls**	***p* for sex**	**Boys**	**Girls**	***p* for sex**
Early morning	53.28 (10.50)	54.91 (9.53)	0.03	64.90 (17.73) †	62.96 (16.63)†	0.29
Mid-morning	67.96 (7.83)	69.97 (7.81)	0.001	56.70 (15.85) †	57.85 (13.63)†	0.26
Morning break	30.46 (14.56)	39.98 (14.04)	<0.001	54.20 (19.81)†	55.05 (17.60)†	0.52
Late-morning	63.21 (9.54)	65.15 (8.71)	0.002	55.47 (14.36) †	55.51 (12.90)†	0.81
Lunch	29.47 (14.40)	36.93 (13.33)	<0.001	57.11 (17.76) †	56.89 (16.20)†	0.99
Early afternoon	61.25 (9.40)	63.24 (9.01)	0.002	56.08 (18.08) †	55.12 (15.62)†	0.75
Late afternoon	54.35 (10.45)	53.34 (9.85)	0.57	57.09 (13.61)**	54.99 (13.69)*	0.14
Evening	63.05 (9.77)	62.55 (9.26)	0.88	65.99 (13.83)**	64.10 (13.99)	0.17

Values represent mean (standard deviation, SD).
P value for sex determined by ANCOVA adjusted for age.
Significant differences within sex between weekday and weekend day proportion of time spent sedentary indicated by: † *p*<0.001, determined by paired sample t-tests.

Frequency of breaks in sedentary time during weekday and weekend day time periods in boys and girls

	Weekday			Weekend day		
	Boys	**Girls**	***p* for sex**	**Boys**	**Girls**	***p* for sex**
Early morning	30.94 (12.97)	32.45 (14.31)	0.10	24.78 (16.97) †	25.68 (17.92) †	0.45
Mid-morning	47.47 (11.69)	46.58 (10.97)	0.15	46.71 (13.23)	48.83 (14.03)*	0.11
Morning break	10.24 (4.19)	12.96 (4.33)	<0.001	13.19 (5.39) †	14.68 (5.29) †	0.002
Late morning	45.54 (11.50)	45.59 (10.30)	0.34	43.92 (12.10)*	47.86 (12.91)**	0.001
Lunch	16.54 (6.29)	20.63 (6.39)	<0.001	22.10 (8.18) †	22.95 (7.94) †	0.50
Early afternoon	35.50 (9.44)	33.71 (9.66)	0.03	32.63 (10.96) †	35.11 (11.44)*	0.01
Late afternoon	62.89 (11.39)	67.08 (11.31)	<0.001	65.14 (17.71)**	69.16 (16.18)*	0.004
Evening	58.54 (22.12)	60.14 (22.37)	0.27	60.42 (30.29)	59.64 (31.77)	0.81

Values represent mean (standard deviation, SD).
P for sex determined by ANCOVA adjusted for age.
Significant differences within sex between weekday and weekend day frequency of sedentary breaks indicated by: † *p*<0.001, determined by paired sample t-tests.

Frequency of 2-5 minute sedentary bouts during weekday and weekend day time periods in boys and girls

	Weekday			Weekend day		
	Boys	**Girls**	***p* for sex**	**Boys**	**Girls**	***p* for sex**
Early morning	3.63 (1.94)	3.81 (1.90)	0.12	3.53 (3.08)	3.58 (2.80)**	0.79
Mid-morning	7.32 (2.00)	7.42 (1.81)	0.58	5.99 (2.84) †	5.95 (2.67) †	0.94
Morning break	0.78 (0.66)	1.11 (0.79)	<0.001	1.61 (1.22) †	1.63 (1.23) †	0.87
Late morning	6.24 (1.61)	6.49 (1.79)	0.15	5.55 (2.45) †	5.36 (2.43) †	0.27
Lunch	1.17 (0.89)	1.51 (0.86)	<0.001	2.72 (1.72) †	2.73 (1.56) †	0.89
Early afternoon	4.60 (1.61)	4.64 (1.56)	0.50	4.05 (2.38) †	3.78 (2.12) †	0.29
Late afternoon	7.89 (2.33)	7.63 (2.16)	0.45	8.22 (3.35)	8.11 (3.39)*	0.99
Evening	8.38 (3.57)	8.08 (3.41)	0.61	8.85 (4.77)	8.26 (4.74)	0.18

Values represent mean (standard deviation, SD).
Differences between boys and girls adjusted for age.
Significant differences within sex between weekday and weekend day frequency of 2-5 minute sedentary bouts indicated by: * p<0.05; ** p<0.01; † p<0.001, determined by paired sample t-tests.

Frequency of 5-10 minute sedentary bouts during weekday and weekend day time periods in boys and girls

	Weekday			Weekend day		
	Boys	**Girls**	***p* for sex**	**Boys**	**Girls**	***p* for sex**
Early morning	1.13 (0.79)	1.01 (0.71)	0.12	1.42 (1.41)	1.17 (1.29)*	0.06
Mid-morning	2.37 (0.96)	2.56 (1.02)	0.02	1.86 (1.49) †	1.79 (1.37) †	0.68
Morning break	0.20 (0.25)	0.24 (0.31)	0.02	0.49 (0.62) †	0.44 (0.60) †	0.50
Late morning	1.82 (0.92)	1.93 (0.88)	0.16	1.53 (1.19)**	1.41 (1.11) †	0.28
Lunch	0.28 (0.33)	0.36 (0.38)	0.001	0.89 (0.84) †	0.75 (0.82) †	0.04
Early afternoon	1.38 (0.70)	1.38 (0.66)	0.70	1.28 (1.19)	1.10 (1.06) †	0.11
Late afternoon	2.51 (1.20)	2.29 (1.15)	0.09	2.78 (1.82)*	2.35 (1.71)	0.01
Evening	2.90 (1.51)	2.88 (1.53)	0.63	3.27 (2.13) †	3.03 (2.06)	0.29

Values represent mean (standard deviation, SD).
Differences between boys and girls adjusted for age.
Significant differences within sex between weekday and weekend day frequency of 5-10 minute sedentary bouts indicated by: * p<0.05; ** p<0.01; † p<0.001, determined by paired sample t-tests.

Frequency of 10-15 minute sedentary bouts during weekday and weekend day time periods in boys and girls

	Weekday			Weekend day		
	Boys	**Girls**	***p* for sex**	**Boys**	**Girls**	***p* for sex**
Early morning	0.34 (0.36)	0.28 (0.35)	0.04	0.58 (0.81) †	0.30 (0.53)	<0.001
Mid-morning	0.59 (0.43)	0.70 (0.47)	0.003	0.44 (0.66)**	0.47 (0.64) †	0.49
Morning break	0.04 (0.12)	0.06 (0.13)	0.02	0.10 (0.25)**	0.10 (0.25)*	0.88
Late morning	0.43 (0.38)	0.52 (0.43)	0.01	0.33 (0.55)*	0.32 (0.52) †	0.76
Lunch	0.06 (0.12)	0.08 (0.15)	0.05	0.21 (0.42) †	0.16 (0.40) †	0.22
Early afternoon	0.35 (0.33)	0.38 (0.35)	0.32	0.32 (0.50)	0.66 (0.52) †	0.14
Late afternoon	0.66 (0.52)	0.59 (0.48)	0.17	0.70 (0.79)	0.57 (0.72)	0.09
Evening	0.81 (0.56)	0.76 (0.55)	0.63	0.89 (0.89)	0.89 (0.93)**	0.78

Values represent mean (standard deviation, SD).
Differences between boys and girls adjusted for age.
Significant differences within sex between weekday and weekend day frequency of 2-5 minute sedentary bouts indicated by: * p<0.05; ** p<0.01; † p<0.001, determined by paired sample t-tests.

Frequency of sedentary bouts longer than 15 minutes during weekday and weekend day time periods in boys and girls

	Weekday			Weekend day		
	Boys	**Girls**	***p* for sex**	**Boys**	**Girls**	***p* for sex**
Early morning	0.17 (0.27)	0.16 (0.25)	0.45	0.29 (0.60)**	0.21 (0.45)	0.19
Mid-morning	0.34 (0.34)	0.39 (0.31)	0.06	0.16 (0.37) †	0.18 (0.40) †	0.60
Morning break	0.40 (0.09)	0.04 (0.10)	0.86	0.06 (0.21)	0.06 (0.20)	0.84
Late morning	0.19 (0.25)	0.24 (0.26)	0.03	0.17 (0.33)	0.20 (0.41)	0.31
Lunch	0.04 (0.10)	0.05 (0.12)	0.38	0.11 (0.28) †	0.10 (0.27)**	0.55
Early afternoon	0.16 (0.22)	0.18 (0.26)	0.08	0.16 (0.35)	0.16 (0.35)	0.99
Late afternoon	0.36 (0.40)	0.28 (0.33)	0.02	0.38 (0.60)	0.34 (0.56)*	0.49
Evening	0.47 (0.44)	0.44 (0.38)	0.65	0.53 (0.67)*	0.45 (0.56)	0.21

Values represent mean (standard deviation, SD).
Differences between boys and girls adjusted for age.
Significant differences within sex between weekday and weekend day frequency of bouts longer than 15 minutes indicated by: * p<0.05; ** p<0.01; † p<0.001, determined by paired sample t-tests.

Percentage of time spent sitting during weekday and weekend day time periods in boys and girls

	Weekday			Weekend day		
	Boys	**Girls**	***p* for sex**	**Boys**	**Girls**	***p* for sex**
Early morning	57.7 (16.4)	54.3 (16.5)	0.20	66.7 (28.4)	65.3 (23.0)†	0.76
Mid-morning	71.4 (13.7)	74.2 (10.0)	0.14	55.5 (26.6)†	53.5 (20.1)†	0.62
Morning break	34.7 (27.4)	33.8 (19.7)	0.81	57.2 (28.7)†	55.6 (25.0)†	0.73
Late-morning	68.5 (15.2)	66.9 (13.2)	0.48	55.0 (22.4)†	57.3 (18.4)†	0.49
Lunch	36.9 (22.6)	35.8 (14.8)	0.72	62.4 (24.5)†	57.9 (22.9)†	0.27
Early afternoon	66.4 (14.4)	67.4 (12.3)	0.64	55.0 (23.8)†	53.3 (19.3)†	0.67
Late afternoon	57.6 (16.4)	53.4 (12.8)	0.09	59.6 (21.6)	57.0 (17.2)	0.44
Evening	63.8 (15.9)	66.8 (12.3)	0.19	67.1 (20.2)	66.7 (18.8)	0.91

Values represent mean (standard deviation, SD).
Significant differences within sex between weekday and weekend day proportion of time spent sitting indicated by: † p<0.001, determined by paired sample t-tests.

Frequency of sit-to-stand transitions during weekday and weekend day time periods in boys and girls

	Weekday			Weekend day		
	Boys	**Girls**	***p* for sex**	**Boys**	**Girls**	***p* for sex**
Early morning	6.6 (4.1)	6.8 (3.9)	0.72	4.9 (3.7)**	6.4 (4.6)	0.06
Mid-morning	12.5 (6.0)	12.1 (4.4)	0.67	9.5 (5.1)**	13.0 (5.9)*	<0.001
Morning break	3.0 (2.2)	3.6 (1.7)	0.04	3.2 (2.1)	3.6 (2.2)	0.28
Late-morning	13.5 (4.8)	12.6 (5.3)	0.28	12.5 (6.1)	13.0 (6.1)	0.61
Lunch	6.6 (3.4)	8.3 (3.8)	0.004	7.2 (3.8)	6.9 (4.1)**	0.74
Early afternoon	9.1 (3.9)	8.8 (3.5)	0.59	10.1 (6.4)	9.3 (5.1)	0.43
Late afternoon	17.4 (6.2)	19.8 (5.6)	0.02	18.6 (9.5)	18.0 (7.6)	0.68
Evening	15.7 (7.5)	17.0 (7.6)	0.27	17.1 (9.5)	16.4 (10.3)	0.70

Values represent mean (standard deviation, SD).
Significant differences within sex between weekday and weekend day frequency of sit-to-stand transitions indicated by: * p<0.05; ** p<0.01; † p<0.001, determined by paired sample t-tests.

Frequency of 2-5 minute sitting bouts during weekday and weekend day time periods in boys and girls

	Weekday			Weekend day		
	Boys	**Girls**	***p* for sex**	**Boys**	**Girls**	***p* for sex**
Early morning	1.33 (0.86)	1.35 (0.92)	0.89	0.84 (1.03)**	1.30 (1.14)	0.02
Mid-morning	3.05 (1.64)	2.73 (1.27)	0.17	1.91 (1.65) †	2.09 (1.44)*	0.52
Morning break	0.37 (0.43)	0.43 (0.40)	0.38	0.60 (0.75)*	0.59 (0.71)	0.89
Late-morning	2.90 (1.54)	2.83 (1.25)	0.77	2.37 (1.85)	2.28 (1.64)**	0.77
Lunch	0.85 (0.63)	1.20 (0.78)	0.003	1.33 (1.10)**	1.20 (1.05)	0.49
Early afternoon	2.06 (1.05)	2.06 (0.95)	0.99	1.72 (1.52)	1.46 (1.12) †	0.27
Late afternoon	3.59 (1.69)	3.69 (1.32)	0.72	3.63 (2.54)	3.22 (2.25)	0.33
Evening	3.14 (1.65)	3.41 (1.63)	0.33	3.54 (2.52)	3.27 (2.36)	0.50

Values represent mean (standard deviation, SD).
Significant differences within sex between weekday and weekend day frequency of 2-5 minute sitting bouts indicated by: * p<0.05; ** p<0.01; † p<0.001, determined by paired sample t-tests.

Frequency of 5-10 minute sitting bouts during weekday and weekend day time periods in boys and girls

	Weekday			Weekend day		
	Boys	**Girls**	***p* for sex**	**Boys**	**Girls**	***p* for sex**
Early morning	0.96 (0.62)	0.95 (0.67)	0.98	0.66 (1.22)	0.97 (0.95)	0.12
Mid-morning	1.95 (0.91)	2.07 (0.86)	0.40	1.13 (1.14) †	1.58 (1.13)**	0.03
Morning break	0.19 (0.27)	0.23 (0.34)	0.47	0.54 (0.61) †	0.46 (0.58)*	0.46
Late-morning	1.87 (0.99)	1.96 (0.90)	0.52	1.29 (1.15)*	1.60 (1.07)**	0.11
Lunch	0.40 (0.37)	0.52 (0.41)	0.08	0.87 (0.76) †	0.76 (0.76)*	0.43
Early afternoon	1.32 (0.64)	1.37 (0.68)	0.63	0.85 (0.74)**	1.04 (1.07)	0.25
Late afternoon	2.25 (1.15)	2.32 (0.88)	0.69	2.17 (1.38)	1.88 (1.31)**	0.21
Evening	1.96 (1.08)	2.28 (1.08)	0.07	2.08 (1.65)	2.22 (1.53)	0.61

Values represent mean (standard deviation, SD) determined by independent t-tests. Significant differences within sex between weekday and weekend day frequency of 5-10 minute sitting bouts indicated by: * p<0.05; ** p<0.01; † p<0.001, determined by paired sample t-tests.

Frequency of 10-15 minute sitting bouts during weekday and weekend day time periods in boys and girls

	Weekday			Weekend day		
	Boys	**Girls**	***p* for sex**	**Boys**	**Girls**	***p* for sex**
Early morning	0.42 (0.31)	0.43 (0.37)	0.89	0.55 (0.77)	0.49 (0.79)	0.66
Mid-morning	0.77 (0.46)	0.98 (0.53)	0.01	0.84 (0.81)	0.78 (0.83)	0.71
Morning break	0.07 (0.14)	0.08 (0.13)	0.93	0.18 (0.32)*	0.18 (0.32)**	0.90
Late-morning	0.89 (0.48)	0.96 (0.46)	0.36	0.64 (0.79)	0.77 (0.75)*	0.33
Lunch	0.11 (0.18)	0.12 (0.18)	0.85	0.41 (0.44) †	0.37 (0.47) †	0.58
Early afternoon	0.57 (0.44)	0.69 (0.39)	0.09	0.35 (0.48)*	0.56 (0.58)	0.03
Late afternoon	1.00 (0.58)	1.11 (0.53)	0.25	0.82 (0.79)	0.97 (0.80)	0.30
Evening	0.94 (0.68)	1.06 (0.62)	0.26	0.88 (0.79)	1.06 (0.98)	0.24

Values represent mean (standard deviation, SD).
Significant differences within sex between weekday and weekend day frequency of 10-15 minute sitting bouts indicated by: * p<0.05; ** p<0.01; † p<0.001, determined by paired sample t-tests.

Frequency of sitting bouts longer than 15 minutes during weekday and weekend day time periods in boys and girls

	Weekday			Weekend day		
	Boys	**Girls**	***p* for sex**	**Boys**	**Girls**	***p* for sex**
Early morning	0.65 (0.45)	0.56 (0.42)	0.19	0.96 (0.93)	0.63 (0.72)	0.03
Mid-morning	1.2 (0.60)	0.35 (0.59)	0.13	0.93 (0.77)*	0.95 (0.82)†	0.91
Morning break	0.06 (0.14)	0.08 (0.14)	0.50	0.18 (0.35)*	0.27 (0.42)†	0.21
Late-morning	1.07 (0.61)	1.05 (0.61)	0.84	0.87 (0.78)	0.93 (0.80)	0.67
Lunch	0.16 (0.24)	0.13 (0.18)	0.40	0.49 (0.53)†	0.51 (0.52)†	0.87
Early afternoon	0.70 (0.42)	0.77 (0.47)	0.38	0.61 (0.64)	0.60 (0.67)*	0.96
Late afternoon	1.19 (0.63)	1.07 (0.61)	0.22	1.32 (1.04)	1.25 (0.98)	0.70
Evening	1.13 (0.72)	1.17 (0.59)	0.67	1.48 (1.10)*	1.34 (1.07)*	0.43

Values represent mean (standard deviation, SD).
Significant differences within sex between weekday and weekend day frequency of bouts longer than 15 minutes indicated by: * p<0.05; ** p<0.01; † p<0.001, determined by paired sample t-tests.

Interactions between total volume of sedentary time, breaks in and bouts of sedentary time and CVD risk factors according to age

There were no positive interactions between the sedentary variables and CVD risk factors according to age (p>0.1).

Interaction between sedentary variables and health outcomes according to age

Interaction according to age	B (SE)*	*p*
Adiposity (n=390)		
WC (n=390)		
Sedentary time	0.110 (0.275)	0.69
Sedentary breaks	-0.008 (0.007)	0.27
2-5 min bouts	-0.019 (0.034)	0.58
5-10 min bouts	0.083 (0.073)	0.26
10-15 min bouts	0.226 (0.219)	0.31
≥ 15 min bouts	0.160 (0.286)	0.58
Blood pressure (n=385)		
DBP (n=395)		
Sedentary time	-0.129 (0.278)	0.65
Sedentary breaks	0.004 (0.006)	0.51
2-5 min bouts	-0.013 (0.039)	0.73
5-10 min bouts	-0.093 (0.079)	0.25
10-15 min bouts	-0.144 (0.171)	0.40
≥ 15 min bouts	-0.379 (0.295)	0.13
SBP		
Sedentary time	-0.088 (0.286)	0.76
Sedentary breaks	0.001 (0.007)	0.88
2-5 min bouts	-0.003 (0.043)	0.93
5-10 min bouts	-0.135 (0.101)	0.19
10-15 min bouts	-0.129 (0.244)	0.60
≥ 15 min bouts	-0.097 (0.276)	0.73

Table 9.16 continued

Interaction according to age	**B (SE)***	***p***
Lipids & CVD score (n=257)		
HDL-C		
Sedentary time	0.008 (0.011)	0.44
Sedentary breaks	0.001 (0.007)	0.76
2-5 min bouts	0.001 (0.002)	0.41
5-10 min bouts	0.003 (0.004)	0.48
10-15 min bouts	0.001 (0.008)	0.87
≥ 15 min bouts	0.003 (0.011)	0.82
LDL-C		
Sedentary time	0.004 (0.022)	0.84
Sedentary breaks	0.000 (0.000)	0.21
2-5 min bouts	0.003 (0.004)	0.46
5-10 min bouts	0.005 (0.007)	0.53
10-15 min bouts	0.006 (0.019)	0.75
≥ 15 min bouts	0.015 (0.028)	0.60
TG		
Sedentary time	0.007 (0.009)	0.46
Sedentary breaks	0.000 (0.000)	0.17
2-5 min bouts	-0.001 (0.002)	0.66
5-10 min bouts	-0.002 (0.003)	0.54
10-15 min bouts	-0.003 (0.007)	0.66
≥ 15 min bouts	-0.003 (0.011)	0.80
z-CVD score		
Sedentary time	-0.074 (-0.124)	0.55
Sedentary breaks	-0.004 (0.003)	0.18
2-5 min bouts	-0.014 (0.015)	0.35
5-10 min bouts	-0.017 (0.034)	0.63
10-15 min bouts	0.025 (0.094)	0.79
≥ 15 min bouts	-0.040 (0.146)	0.79

Abbreviations:WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; TG, triglycerides. CVD score, clustered cardiovascular risk score determined by the standardized and sum of waist circumference, low density lipoprotein cholesterol, inverted high density lipoprotein cholesterol and triglycerides.
* Reported to three decimal places on account of small values