Does sedentary behaviour contribute to chronic disease or chronic disease risk in adults?

A report prepared by the
Scientific Committee of
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Background

Sedentary behaviours include sitting time at work, reading, sitting while travelling, computer time and television viewing. Increased sedentary time may substantially increase risk of chronic disease (Hamilton et al 2007). This increased risk may be independent of habitual physical activity levels. That is, the potential negative effects from so many hours of sedentary activity every day may not be negated by bouts of moderate to vigorous physical activity a few times a week. In contrast to the large amount of epidemiological, basic scientific (both cellular and physiological) and intervention data about exercise, little is known about the cellular signals, physiological responses and disease outcomes of prolonged sitting and other sedentary behaviours.

Aims

The aim of the report was to answer the following questions:

1. What is the context for sedentary behaviour in the adult population? For example:
   - What is sedentary behaviour and how has it been defined/conceptualised?
   - Is sedentariness prevalent among adults?
   - How is sedentary behaviour measured?

2. What are the associations between adult sedentary behaviours and chronic disease and chronic disease risk (and other social factors/behaviours such as productivity, cognition and food intake[1])?
3. What interventions/environments are effective in reducing adult sedentary behaviours?
4. What are the recommendations for sedentary time for the adult population?

Methods

Databases of scientific publications and relevant websites were searched for papers published from January 1996 to 21 November 2008, a time span chosen to make the analyses manageable. The search terms and an example strategy are provided at the end of the methods section. Additional searches on key author surnames were also undertaken.

What is sedentary behaviour?

Sedentary behaviour should be viewed as a discrete behaviour separate from physical activity. For this review, activities with a metabolic equivalent (MET, where 1 MET is

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[1] No papers about sedentary behaviour relationship with cognition or worker productivity were found.

amount of energy used when completely at rest) of less than 1.5 are classified as sedentary behaviour (Pate et al 2008). Also for the purpose of this review, at least one indicator of sedentary behaviour had to be measured in some way; for example, time spent watching television (TV), time spent using a computer or gaming, time spent sitting at work, and/or time spent reading.

How much time do people spend in sedentary pursuits?

There is a marked lack of measurement of sedentary behaviour in New Zealand's large nationwide surveys. One measure of sedentary behaviour comes from the New Zealand Time Use Survey, where participants were asked to record time spent watching TV or videos. Nine out of ten (88%) respondents watched TV, making this the most popular leisure time activity of New Zealanders. On average, people watched just under two hours (1 hour 59 minutes) of TV or videos per day as a primary activity (Statistics NZ 2009).

The only population-based prevalence sample that used an objective measure of sedentary behaviour is the National Health and Nutrition Examination Survey (NHANES) 2003/04, which sampled 6329 participants in the USA. Results showed that children and adults in the USA spent 54.9% of their waking time, or 7 hours 42 minutes per day, in sedentary behaviours (Matthews, et al 2008).

How is sedentary behaviour measured?

Valid and reliable measurement of sedentary behaviour is important. Like physical activity measurement, sedentary behaviour measurement has used self-report, energy expenditure and motion sensors to try to understand the degree to which people move, or do not move. Motion sensors probably provide the best option across a range of research questions for measuring sedentary behaviours. They are less costly and more portable than energy expenditure methods, and are not prone to recall problems experienced in self-report. They are also likely to be suitable across a range of ages, from young children to older adults, making comparisons using the same units feasible.

Associations between sedentary behaviour and health

The literature review shows there is some evidence that sedentary behaviour may adversely affect health and health risk. The studies are mainly cross-sectional, with a few prospective studies emerging recently. The first prospective study[2] to use a sample that is representative of a general population is the 14-year follow-up of nearly 20,000 Canadians in the Canadian Fitness Survey (Katzmarzyk et al 2009). In this study, increasing sitting time was associated with higher all-cause death and cardiovascular disease death, but not cancer death. These effects persisted independently of physical activity measures.

[2] A study that follows people over time to see if ill health results from earlier behaviours.

Obesity

Out of 51 studies, 38 (29 cross-sectional and nine prospective) reported significant positive associations between sedentary behaviour and obesity, 12 reported no association (10 cross-sectional and two prospective). No studies showed a negative association. Taken together, there is considerable evidence that sedentary time is associated with increased risk of obesity *per se* and weight gain in lean people. At this stage more robust measurement and consistency of measurement across studies is required. We conclude there is sufficient evidence, both in terms of plausible mechanisms and epidemiological evidence, that sedentary time is associated with increased risk of obesity *per se* and weight gain in lean people, and to alert the public to the risks of high TV time, occupational sitting and high sedentariness in general.

Metabolic syndrome

Out of 19 cross-sectional studies, 14 reported significant positive associations between sedentary behaviour and metabolic syndrome and five reported no association. No studies showed a negative association. Taken together we have only a limited amount of epidemiological evidence, confined to cross-sectional studies, for an association so it is premature to discuss the magnitude of these effects.

Diabetes

All three reviewed studies (one cross-sectional and two prospective) reported significant positive associations between sedentary behaviour and diabetes. No studies reported no association and no studies showed a negative association. More work needs to be carried out, but we can conclude that there is some evidence for this link.

Cardiovascular disease and dyslipidaemia

All four reviewed studies (two cross-sectional and two prospective) reported significant positive associations between sedentary behaviour and cardiovascular disease and dyslipidaemia. No studies reported no association, and no studies showed a negative association. Although there are only a few studies, there is some evidence that sedentary behaviour is an independent risk factor for cardiovascular disease.

Cancer

On balance the evidence for sedentariness causing cancer is limited. There are few studies with equivocal results. More evidence is needed before drawing conclusions or making public health recommendations for reducing cancer risk. Certainly there is a plausible link, with some prospective evidence for some cancers at this stage.

Back pain, bone health, gallstones and mental health

There has been limited investigation into other outcomes such as back pain, bone health, gallstones and mental health. All of the associations reported are in cross-sectional studies. More research needs to be carried out to draw conclusions about an effect for these outcomes.

Interventions to reduce sedentary behaviour

Few studies have examined interventions to reduce sedentary behaviour. Some studies have been undertaken within the workplace such as standing work stations, and interventions incorporating a low-speed treadmill (Levine et al 2008). Workplace sitting is highly prevalent in most office environments and therefore appears to be a great place to start intervention. Levine and colleagues substituted a traditional sit-down desk for a desk that incorporates a low-speed treadmill into its design. Instead of sitting it is possible to walk at 1 to 2 km/h while working on office-based tasks such as talking on the telephone and undertaking computer work.

Within a community setting programmes that encourage or support increased light or moderate activity such as walking and/or use of pedometers (De Cocker et al 2008) may reduce sedentary behaviour. The 10,000 Steps approach in Belgium saw a 30-minute differential in sitting time at follow-up in the intervention community compared to the control communities (i.e. the intervention community reduced sitting time).

Recommendations and future work

Sedentary behaviours need to be addressed

Although this field is still very much in the development stage, there is sufficient evidence to suggest that sedentary behaviour is a distinct risk for multiple health outcomes and that this risk appears to be independent of time spent doing moderate and/or vigorous physical activity. Because of the lack of measurement of sedentary behaviour, there is insufficient evidence to explain the nature of the relationship between sedentary behaviour and multiple health outcomes, and how much sedentary time is acceptable. Therefore, more research is required.

It is important to acknowledge the role that light activity and habitual movement (e.g. slow walking, walking around the house/office) may play in health, and especially in energy expenditure.

We recommend:

1. <u>Research:</u> investigating doses and levels of sedentary behaviour and the resulting disease risk to inform policy decisions and help develop recommendations and guidelines. Evidence gaps are detailed in the section below.

2. <u>Policies and Guidelines:</u> Government agencies such as the Ministry of Health, SPARC and Department of Labour consider the role of sedentary behaviour when developing policies and guidelines.

Disseminating the message

The simple message is to “move more, sit less”. Dissemination of this message can occur in a variety of different settings including workplaces, primary care settings, sport and recreation, and public health, as well as the wider community.

Evidence gaps

At present there are several gaps in the research literature; filling these will provide important evidence for policy and action in this area. Research priorities include:

- Epidemiology: measuring how sedentary New Zealanders are, trends, and which population groups have the highest levels of sedentariness.
- Epidemiology: further detailed epidemiological work, especially prospective studies that incorporate objective measures to understand the health outcomes associated with high levels of sedentary behaviour.
- Physiology: further physiological work investigating the effect of sedentary behaviour on biomedical outcomes related to glucose metabolism and blood lipids. This will build on research already underway and well reviewed by Hamilton et al (2007).
- Environmental influences: investigating the macro and micro (e.g. settings-based) environmental factors that promote sedentariness.
- Interventions: researching the efficacy of environmental re-engineering to promote standing and ambulatory pursuits, which should be both in the broader urban environment and specific to settings such as workplaces, schools and social settings.

Intervening across settings

Approaches that involve changing sedentary behaviour in specific settings are likely to be effective. We suggest workplace and family/whānau settings are appropriate places to make improvements.

In the workplace many adults spend long periods of time sitting. We suggest organisations could adopt the following approaches:

- Acknowledge sedentary behaviour is a workplace health and productivity issue and address sedentary behaviour in a systematic way.
- Provide vertical (or height-adjustable) work stations for employees that allow workers to stand for part of the day while continuing to work at computers and other office/factory equipment. Treadmill-based work stations could be considered by workplaces in the future.
- Encourage staff to "walk and talk" where practical, by moving about the workplace when communicating with each other rather than using email, phones and seated meetings.
- Encourage staff with largely sedentary tasks to take breaks that involve movement of some kind.

Home environments are often characterised by long periods of sitting, especially watching electronic media. At the individual and family/whānau levels we suggest the following interventions may be effective in reducing sedentariness:

- Think of movement as an opportunity, not an inconvenience (e.g. park the car a little further away from destinations, view household chores positively as activities that increase energy expenditure).
- Reduce TV viewing and recreational screen time. Preferably less than two hours a day, the less screen time the better.
- Walk, cycle or use public transport to commute and move about. Minimise car and motorcycle use, and consider car-free days.
- Be active in as many ways as possible. If you fidget, or like to pace while talking on the phone, keep doing so.
- As a family, look for ways to modify your household environment to increase movement and minimise sitting time (e.g. household computer stations could be modified to allow standing at computers).
- Labour-saving devices are not essential household items, manual tasks help to contribute to higher energy expenditure.
- When participating in recreation and hobbies, consider how you can reduce sedentary behaviour associated with that recreation and hobby.
- When socialising with friends, consider options that include movement (e.g. grab a coffee-to-go and walk while you socialise).

1. Background

1.1 Introduction

Sedentary behaviours include sitting time at work, reading, sitting while travelling, computer time and television (TV) viewing. TV viewing has been the focus of many studies which show that watching TV is associated with increased body weight and obesity in children. The strongest evidence explaining the relationship was through an adverse effect on dietary intake rather than from displacement of activity (Taylor, Scragg, & Quigley, 2005). This report moves beyond the previous Agencies for Nutrition Action report titled *Does Watching Television Contribute to Body Weight and Obesity in Children?* in which the association between obesity and TV watching among children was examined. Here we investigate the relationships between all forms of sedentary behaviours (rather than just watching TV) undertaken by adults (rather than children) on multiple outcomes of chronic disease (rather than just body weight).

Like increased physical activity, decreasing time spent in a sedentary state is of significant interest to government given the many positive health and wellbeing outcomes that can accrue from reduced sedentariness. Reducing sedentary behavior requires equal attention at both the government and local community levels to help improve the health and wellbeing of adults, similar to the importance of regular activity as reflected in:

- government policy (e.g. the Healthy Eating − Healthy Action strategic approach (Ministry of Health 2009)
- programmes (e.g. SPARC's Push Play)
- investment approaches (the level of investment in organisations that promote activity)
- the numerous community-level physical activity initiatives that currently exist
- the level of investment in organisations that promote activity (SPARC 2009).

Other reviews have already identified the significant benefits to both adults and children from physical activity (US Department of Health and Human Services 2008), presented various approaches to increase activity (Foster et al 2005), quantified the global burden of chronic disease attributable to physical inactivity (Bull 2004) and underpinned the development of setting physical activity guidelines for adults (Haskell & Lee, 2007; Saris, et al., 2003). Such reviews of physical activity complement this work on sedentary behaviours in adults.

However, these physical activity reviews can often confuse sedentary behaviour issues by:

- defining individuals as "sedentary" when they do not take part in a particular level of moderate-to-vigorous physical activity.
- scantily covering measured sedentary behavior.
- implying time spent in sedentary behaviour is directly related to time spent being physically active.

- using the terms "physically inactive" and "sedentary" interchangeably, with no specific definition of either.
- making recommendations that could be wrongly taken to be about measured sedentariness despite the above issues.

Sedentary behaviour sits within a broad set of influences, and because sedentary behaviours may occur across several dimensions, these influences and relationships between them may be complex and multi-level. The Scientific Committee members have developed an ecological model based on their past experience, combined with information gained from this review process. The model describes how adult wellbeing outcomes are influenced not only by immediate factors such as sedentary behaviours, but also by more distant factors such as work–life balance, physical activity, urban design, and society's expectations for how adults should act.

Understanding the sequence of events that cause sedentary behaviour and understanding what works to make adults less sedentary depends on the theoretical model underpinning the work. The model we have developed reflects how sedentary behaviour can impact on multiple outcomes within a wider community context, as shown in Figure 1. The areas shaded in light yellow are covered by this literature review. The framework conveys the notion that what happens in one environment influences, and is influenced by, what happens in another. The Scientific Committee members understand that sedentary behaviours are likely to be unevenly distributed throughout society and that some of the causes of these behaviours may be structural. The review presents the findings as one part of the evidence about sedentary behaviours.

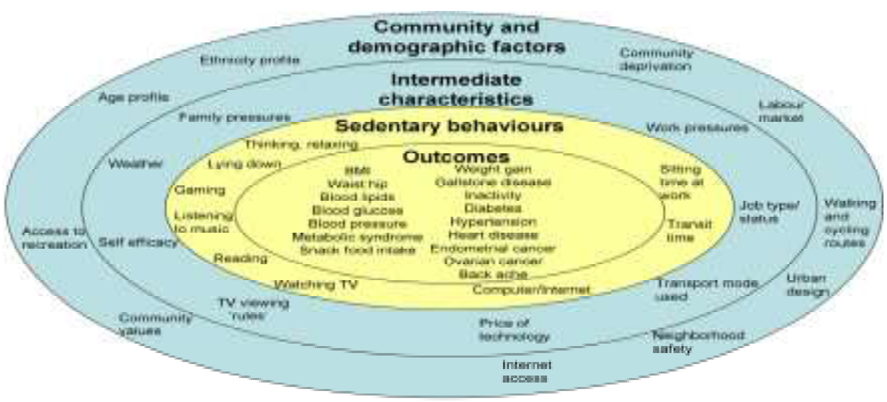

Figure 1:
Model of determinants of sedentary behaviour and outcomes of interest

1.2 Aim of the report

When deciding the outcomes of interest for this literature review, obesity and overweight were acknowledged to be key concerns in the current New Zealand context by the Scientific Committee members. However, other factors such as chronic diseases, worker productivity and/or cognition and/or mental health outcomes may also be affected by sedentary behaviour. Therefore this review searched for any impact on these factors as well.

The aim of this report was to answer the following questions:

1. What is the context for sedentary behaviour in the adult population? For example:
   - What is sedentary behaviour and how has it been defined/ conceptualised?
   - Is sedentariness prevalent among adults?
   - How is sedentary behaviour measured?
2. What are the associations between adult sedentary behaviours and chronic disease and chronic disease risk (and other social factors/behaviours such as productivity, cognition and food intake[3])?
3. What interventions/environments are effective in reducing adult sedentary behaviours?
4. What are the recommendations for sedentary time for the adult population?

1.3 Defining and conceptualising sedentary behaviour

1.3.1 What are metabolic equivalents?

Metabolic equivalents (METs) express energy expenditure in multiples that are relative to an individual's resting metabolic rate. One MET represents the rate of oxygen consumption (VO_2) of approximately 3.5 mL oxygen/kg/minute for an average adult sitting quietly. An individual performing an activity of 3 METs has a VO_2 three times higher than that while sitting quietly. Another way to imagine how a MET works is that the energy used from very slow walking (which has a MET of 2.0) increases whole-body energy expenditure by 2.0 times more than when seated still (Ainsworth 2000; Levine et al 2000).

1.3.2 How was sedentary behaviour defined for this review?

For this review, activities with a MET of ≤ 1.5 are classified as sedentary behaviour (Pate et al 2008). Also, for the purpose of this review at least one indicator of sedentary behaviour had to be measured in some way; for example, time spent watching TV, time spent using a computer or gaming, time spent sitting at work, and/or time spent reading.

The METs for sedentary behaviours included in this review are listed in Table 1 and are those often described as "very low intensity". Low-intensity MET values of > 1.5 to < 2.0 (where standing equates to 1.8 METs) have not been included in our definition of sedentary behaviour because light-intensity activity (such as standing) may be important in closing the energy gap through non-exercise thermogenesis and may also have attributable health benefits. Furthermore, including articles on low-intensity activity would have broadened the scope of the review, significantly increased the number of

[3] No papers about sedentary behaviour relationship with cognition or worker productivity were found.

papers to be appraised for this review, and potentially reduced content clarity. Other physical activities are typically categorised in absolute terms as "light" (< 3 METs), "moderate" (3 to 6 METs) or "vigorous" (> 6 METs) (Haskell & Lee, 2007).

Table 1: Behaviours included or nor included in this review

Sedentary behaviours included in this review		Behaviours not included in this review	
MET	Activity	MET	Activity
		1.8	Standing, talking
1.0	Watching TV, lying down or reclining while reading, writing, talking	2.0	Walking slowly around house
1.2	Standing quietly in a line	2.3	Standing at work, bartending, filing, duplicating, washing dishes at home
1.3	Sitting while reading a book or newspaper	3.3−3.5	Walking, moderate pace, for pleasure
1.5	Sitting while using a computer, sewing, typing, light office work, meetings, reading, driving, talking and eating	3.5	Vacuuming
		3.7–5.0	Sexual activity
		4.9 (Moy et al 2006)	Kapahaka
		5.0	Walking very briskly
		7.0	Jogging (general)
		7.1 (Moy et al 2006)	Haka
		8.0	Cycling (general)
		10.0	Running (10 km/h)
		18.0	Running (17.5 km/h)

Source: Ainsworth et al 2000.

1.3.3 The difference between sedentary behaviours, sedentary lifestyle, NEAT and physical (in)activity

Physical activity

Physical activity is defined as "any bodily movement produced by skeletal muscles that results in energy expenditure" (Caspersen, Powell, & Christenson, 1985). Descriptions used in many physical (in)activity studies such as "sedentary" or "sedentary lifestyle" have most often been determined from a participant's reported physical activity level, where the participant did not reach a set level of activity. Most of the studies asked questions about moderate-to-vigorous physical activity behaviours only, and did not attempt to capture answers about light or sedentary activities. That is why many studies of physical activity have large proportions of the population who appear to do nothing at all, registering zero minutes per week of moderate-to-vigorous activity, and so are classed as "sedentary" by those authors.

Authors also often use the terms "inactive" and "sedentary" interchangeably, as though there is no difference. Inactivity as defined in this manner is actually the absence of moderate-to-vigorous physical activity (Pate et al 2008). Spanier et al (2006) summed it up nicely when they said most research currently focused on, and measured, what people are *not* doing (inactive because of lack of moderate-to-vigorous activity) rather than what people *are* doing (sedentary behaviours).

Non-exercise activity thermogenesis (NEAT)

The class of behaviours that contribute to energy expenditure but fall below usual measurement of moderate-to-vigorous physical activity are categorised as non-exercise activity thermogenesis (or NEAT). This form of thermogenesis can account for a substantial proportion of daily energy expenditure, usually substantially more than the sum of daily moderate-to-vigorous activities (Hamilton et al 2007). NEAT is calculated from a combination of body positions used when taking part in normal everyday activities (sitting, standing, lying down, but not sleeping), and the transition between these, plus fidgeting. In terms of the energy gap implicated in the formation and maintenance of population levels of overweight and obesity, understanding and increasing NEAT has the potential to significantly add to daily energy expenditure.

Sedentary lifestyle definitions

Many organisations use definitions for sedentary lifestyles similar to that used by the World Cancer Research Fund, which leave room for confusion, as seen below.

Definitions of "sedentary lifestyle" used by the World Cancer Research Fund (2007)
< 30 minutes of moderate physical activity (equivalent to brisk walking) on fewer than 5 days per week.
< 20 minutes of vigorous physical activity (equivalent to running) on fewer than 3 days per week.
< 60 MET hours of any combination of activity on fewer than 5 days per week.

1.3.4 Why definitions are important

Research is hampered

The US Guidelines for Physical Activity say activity less than 3.0 METs does not count towards meeting the physical activity guidelines (US Department of Health and Human Services 2008). Cut-offs such as these are part of the reason why so little research has been carried out on sedentary behaviours (METs < 1.5) and the remaining light behaviours (METs 1.5–2.9). These cut-offs ignore the cumulative importance of light behaviours over extended periods of time.

Bennett et al (2006) reviewed the different definitions of sedentary behaviours used in published physical activity intervention trials, and commented that "the range of definitions makes it difficult to compare trial results or generalise findings". When comparing sedentary behaviour (sitting time) as measured by an accelerometer, and categories of activity (i.e. the inactive category) by the short- and long-form International Physical Activity Questionnaire (IPAQ) in a three-nation study, there was no agreement between the two measures in terms of identifying sedentary adults. The authors concluded "sedentary behaviour should be explicitly measured in population surveillance and research instead of being defined by lack of physical activity" (Rosenberg et al 2008).

Many reviews by authoritative organisations have referred to and defined sedentary behavior in a way that is incongruent with current research and has led to ongoing confusion in sedentary behaviour issues by:

- defining individuals as "sedentary" based on the absence of moderate-to-vigorous physical activity rather than actual sedentary behaviours
- ignoring or scantily covering measured sedentary behavior
- implying time spent in sedentary behaviour is directly related to time spent being physically active
- making recommendations about sedentary behaviour despite having studied physical inactivity
- using the terms "inactive" and "sedentary" interchangeably with no specific definition of either.

Impact is underestimated

Spanier et al (2006) concluded that large proportions of populations are inactive already (under a typical physical activity definition), and that such inactive people cannot increase their risk of disease by becoming "less active" because they are already in the lowest category of activity. In fact, such inactive people may be able to substantially increase their risk of chronic disease by further increasing sedentary behaviours (Hamilton et al 2007). Hamilton et al argue for inactive people, a high proportion (over 90%) of their total energy expenditure is expended through standing and non-exercise or incidental moving around. This is because their total daily energy expenditure is so low as a result of their lack of exercise and the length of time they sit. Furthermore, even the most inactive people (based on physical activity level) stand and move at least one hour a day, if not for many hours each day. The potential for reducing this time (and increasing sedentary behaviours) is still incredibly high for inactive people, yet the potential to become "less moderately or vigorously active" remains nil. Hamilton et al (2007) sum the point up by saying:

> *"the pinnacle of human inactivity is highly unlikely to have arrived given the continuation of technological and sociological changes that are progressing human inactivity. There is therefore a significant potential for future disease risk from people becoming more sedentary" (p. 2657).*

Time spent on moderate-to-vigorous activity has little bearing on sedentary behaviour

Based on a large representative sample of US adults, Ford et al (2005) concluded that spending time on moderate-to-vigorous physical activity (greater than 150 minutes per week) had little bearing on spending time on measured sedentary behaviour, and vice versa. Ford et al went on to say: "measuring participation in physical activity and measuring sedentary behaviour provide independent measures of the activity spectrum of individuals and may provide independent information about the risk of future disease" (p. 613).

Different determinants and independent risks

As well as being different and unrelated behaviours, physical activity and sedentary behaviours may have different determinants and independent risks for diseases (Hamilton et al 2007). In contrast to the large amount of epidemiological, scientific (both cellular and physiological), and intervention data about exercise, little is known about the cellular signals, physiological responses and disease outcomes of prolonged sitting and other sedentary behaviours. For example, the signals of harming the body from too much inactivity may not be the same as those signals boosting health from sufficient exercise (Hamilton et al 2007). Similarly, the potential negative effects associated with extended periods of sedentary behaviour may not be offset by bouts of moderate-to-vigorous physical activity. One recent example of this is deep venous thrombosis (DVT), which is caused by sitting for long periods and not by lack of moderate-to-vigorous activity. This review will identify other outcomes that are differently affected by sedentary behaviour and physical activity.

Being physically active may not negate sedentary behaviour

Being "physically active" (i.e. meeting a predetermined level of moderate-to-vigorous physical activity) may not be sufficient to offset the negative effects of other time spent being sedentary. People who are known to be active according to physical activity guidelines (e.g. > 2.5 hours per week of moderate-to-vigorous physical activity) can still have their health affected by being sedentary. For example, Healy et al (2008a) showed that for healthy Australians who met the guidelines for physical activity, TV viewing time was positively associated with a number of metabolic risk factors and not associated with others. There was also a dose‒response relationship for some of the associations; i.e. when TV watching increased, so did the metabolic risk. For example, for every increase in female participants' TV viewing category (from 0.71 hours/day to 1.43 hours/day; to 1.44 hours/day to 2.14 hours/day; to > 2.14 hours/day), waist circumference significantly increased (1.65 cm; 1.83 cm; 4.22 cm) compared to those in the lowest TV viewing category (Healy et al 2008a).

1.4 Sedentary behaviours and energy expenditure

1.4.1 Contribution of sedentary behaviours and light activities to energy burned

Time spent stepping (i.e. walking), standing and sitting can vary significantly among people. Figure 2 below (from Hamilton et al 2007) compares two people with differing activity levels. The top graph shows a person who spends more time standing and in light activity, whereas the bottom graph shows a person who spends most of their time sitting. The difference in the amount of "sedentary" (i.e. sitting) time is significant.

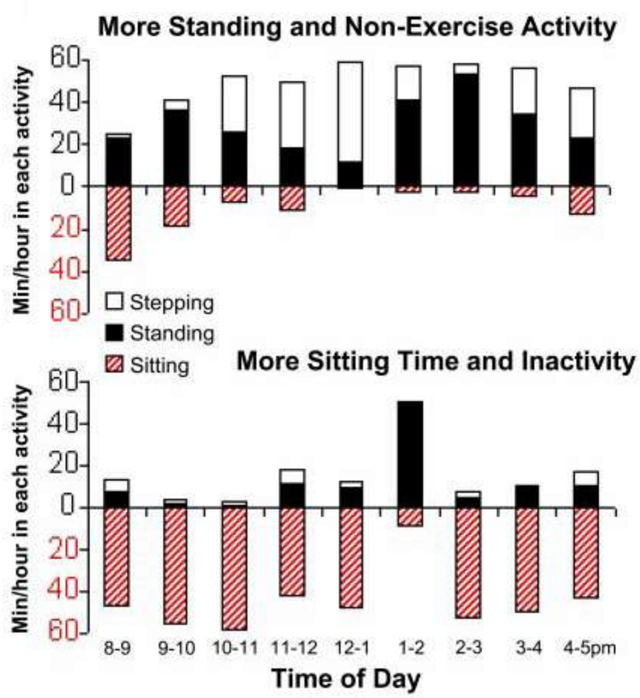

Figure 2. Comparison of two people's time spent in activities
Source: Hamilton et al 2007

Figure 3 shows the relative increase in energy expenditure over and above energy expended from NEAT for a reference person weighing 70 kg when he/she walks 30 minutes a day, walks 60 minutes a day, or runs more than 35 miles per week (Hamilton et al 2007). This figure demonstrates that most of the weekly energy expended by a person from all forms of activity is that expended from NEAT, and that the exercise component − be it walking for 30 minutes or 60 minutes, or running − is the minor component.

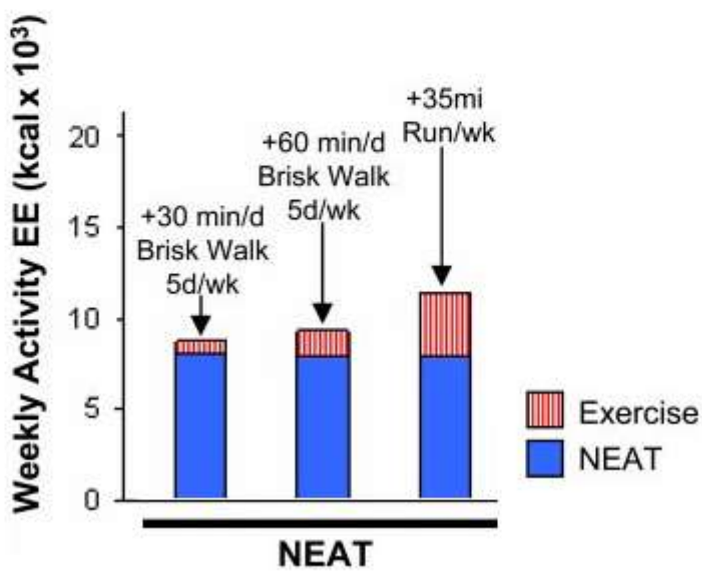

Figure 3: Energy expended from different activities
Source: Hamilton et al 2007

In one study of fidgeting in a carefully controlled environment, the results showed that fidgeting while sitting (54% increase) or standing (94% increase) significantly increased the energy expenditure of subjects. Also, as the body mass index (BMI) of the participant increased, more energy was expended during fidgeting while standing (possibly because while standing a greater body weight is being supported) but not during fidgeting while sitting. The authors concluded that fidgeting has the potential to substantially contribute to energy balance (Levine et al 2000).

1.4.2 Impact of labour-saving devices on daily energy expenditure

Examples of labour-saving devices include washing machines, dishwashers, escalators and vehicles. Labour-saving devices reduce energy expenditure when the tasks associated with such devices replace the old-fashioned way (e.g. driving rather than walking to work, using a washing machine instead of washing clothes by hand). Lanningham-Foster et al (2003) investigated the amount of energy expended using labour-saving devices compared with not using them. Not surprisingly, mechanical dish-washing and mechanical clothes-washing, driving to work, and taking the lift or escalator removed an average of 111 kcal per day from people's total daily energy expenditure when measured against the sum of the more active counterparts. This difference in energy expenditure was described by the authors as "sufficiently great to contribute to positive energy balance associated with weight gain". Interestingly, this is nearly identical to the amount of energy expended during 30 minutes of brisk walking (117 kcal), and that associated with the current obesity epidemic (Hill, Wyatt, Reed, & Peters, 2003).

1.5 The prevalence of adult sedentary behaviour

1.5.1 New Zealand evidence

The lack of focus on measured sedentary behaviour is also reflected in New Zealand's large nationwide surveys. Neither the adult National Nutrition Survey of 1997 nor the New Zealand Health Surveys of 2002/03 and 2006/07 measured sedentary behaviour or TV viewing for adults. The 2006/07 New Zealand Health Survey asked a question about children's TV viewing but not adults' TV viewing. The 2008/09 adult National Nutrition Survey does not have a question relating to TV viewing or other sedentary behaviours.

One measure of sedentary behaviour comes from the New Zealand Time Use Survey, where participants were asked to record time spent watching TV or videos as one of the categories. Nine out of ten (88%) respondents watched TV, making this the most popular leisure time activity of New Zealanders. On average, people watched just under 2 hours (1 hour 59 minutes) of TV or videos per day as a primary activity, in addition to a further 48 minutes a day as a simultaneous activity when engaged in some other task, such as reading, child minding, preparing meals or eating (2 hours 47 minutes total). Overall, males watched slightly more TV and videos than females: males spent 2 hours 10 minutes as a primary activity watching TV and a further 42 further minutes per day watching TV as a simultaneous activity (while they were also engaged in other tasks); females watched 1 hour 49 minutes per day as a primary activity and 54 minutes as a simultaneous activity (Statistics NZ 2009).

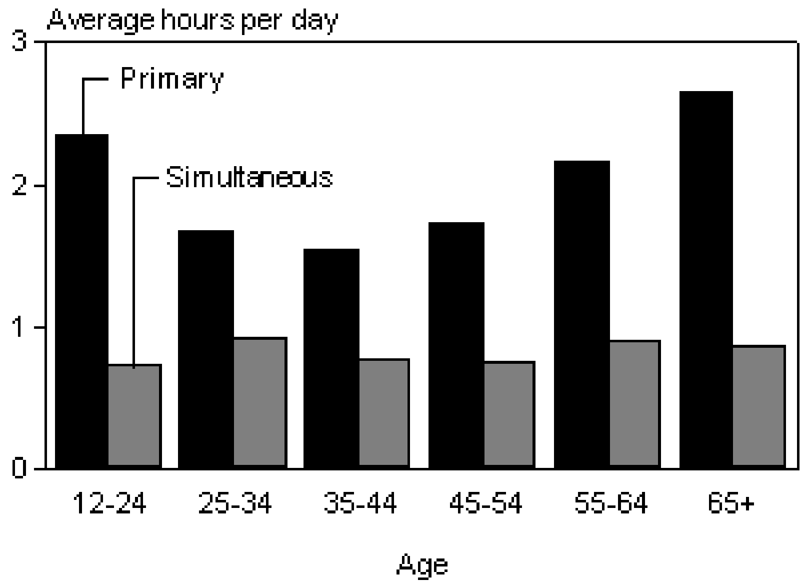

Figure 4: Average hours per day spent watching TV or video, by priority of activity and age
Source: Statistics NZ 2009

As shown in Figure 4, those who spent the most time watching TV or videos were in the youngest and oldest age groups. New Zealanders aged 12−24 years watched on average a total of around 3 hours of TV or videos daily (as either a primary or simultaneous activity), as did those aged 55−64. But the greatest amount of viewing was done by New Zealanders in the retirement age group, who spent an average of around 3.5 hours a day watching TV or videos. In the intervening age groups, when people's family responsibilities and involvement in the paid labour force are greater, less time is spent watching TV or videos. In addition, a greater proportion of this is done as a simultaneous activity, often in combination with domestic duties such as caring for families.

The above data agree closely with the only other data source available on TV viewing, which is from the New Zealand Television Broadcasters' Council. This shows people aged five years and upwards watch TV on average 3 hours and 8 minutes per day, up from 2 hours 53 minutes per day in 2007 (New Zealand Television Broadcasters' Council 2009).

In the 2007/08 Active New Zealand Survey, SPARC assessed two indictors of sedentary behaviour: time spent sitting watching TV, DVDs or videos per day and computer time (excluding work/school time) per day. A seven-day recall was used to assess total daily time per indicator. The results are yet to be published.

One experimental study (Rush et al 2008) of 29 New Zealand men (10 NZ European, 10 Māori, 9 Pacific people) was undertaken in which a seven-day diary was kept (recording 15-minute intervals of activity). The authors analysed time spent "static". Unfortunately this included time spent lying, sitting and standing as a category, and with a finding of an average of 18 hours per day of "static" it clearly also included sleeping in the category. This was because the purpose of the study was to test the validity of the seven-day diary method against a gold standard, and was not attempting to determine the prevalence of sedentary behaviour.

1.5.2 International evidence

A number of studies have attempted to measure sedentary behaviour, using various methods. These are presented in Appendix 2. Only four studies will be discussed in this introduction because they used an objective measure of sedentary behaviour, and only one of these studies contains a large population sample. Many studies reported in Appendix 2 have used diary and recall methods that have attempted to record/recall a wide mix of data, including TV watching, reading, sitting time at work, screen time and travelling time.

The only population prevalence sample that used an objective measure of sedentary behaviour is the 2003/04 National Health and Nutrition Examination Survey (NHANES), with data collected from 6329 (children and adults) in the US. On average, participants wore the accelerometer for 13.9 hours per day for five days. Results showed that, on average, participants spent 7 hours 42 minutes per day in sedentary behavior (as defined by accelerometer counts below 100 counts/minutes); this equates to 54.9% of their daily waking hours (Matthews, et al., 2008).

Furthermore, the sedentary behaviour of adults increased at every age bracket, from 7 hours 29 minutes for 20−29 years, through to 9 hours 17 minutes per day for 70−85 years (the most sedentary group). Those aged greater than 50 years had a sedentary level equal to or higher than that of adolescent boys or girls. Females were more sedentary than males through youth and adulthood, but beyond 60 years this was reversed. Mexican Americans were less sedentary than either Blacks or Whites at all age groups. Interestingly, media time, which is a common proxy measure for sedentary behaviour, accounted for about half of the overall time spent in sedentary behaviour by the US population (Matthews et al 2008).

The authors noted two conclusions relevant to their study. First, using an objective measure of sedentary behaviour meant the time spent in sedentary behaviours was nearly twice that of other single-measure or media-based assessments of sedentary behaviour. Secondly, previously described US studies that showed differences of time spent by specific population groups watching TV did not translate into actual differences in overall sedentary time between those population groups. For example, previous reports found that 40% of Black children watch over 4 hours of TV per day, while only 20% of White children reported that much TV viewing. In the NHANES study, this difference did not translate into objectively measured differences in overall sedentary behaviour between Black and White children – they were both equally sedentary (Matthews et al 2008).

Three other studies that used objective measures for sedentary behaviours also reported significant amounts of time spent in sedentary behaviours. Among 169 Australian adults, 57% of their waking hours (waking hours not defined) were spent in sedentary behaviours. Swedish males (n = 87), Swedish females (n = 98,)English males (n = 103) and English females (n = 155) spent at least 7 hours in sedentary behaviour per day (7 hours 0 minutes, 6 hrs 34 minutes, 7 hours 13 minutes, 6 hours 41 minutes, respectively). None of these three studies were designed to predict prevalence of sedentary behaviour, but they do give an accurate indication of the time spent in sedentary behaviours for these non-representative samples.

Data of interest from the other studies of measured sedentary behaviours are briefly described below.

- In a phone survey of Australian workers, age and job status determined time spent sitting. Male and female managers (4 hours 44 minutes and 3 hours 24 minutes) sat longer than male and female white-collar workers (3 hours 22 minutes and 3 hours 28 minutes), who sat longer than male and female blue-collar workers (2 hours 22 minutes and 2 hours 46 minutes). Male workers aged less than 30 years reported at least 50 minutes less sitting time than older age groups (Mummery et al 2005).
- Forty-three percent of American adults watched more than 2 hours of TV per day according to the NHANES 1999/2000 study (Ford et al 2005).
- Those with a low level of education and from low-income households were significantly more likely to watch more than 2 hours of TV per day according to the US Department of Agriculture’s Continuing Survey of Food Intake by Individuals survey (Bowman 2006).
- In a phone survey of Australian households, one in three “highly active people” watched more than 2.5 hours of TV per day. Over half watched between 1 and 2.5 hours, and just over one in ten watched less than 1 hour of TV per day (Salmon et al 2000).
- In a household survey of Dutch workers, regardless of sitting time during the day (“higher-status employees” sat for longer), evening sitting times differed only slightly between occupational groups (Jans, Proper, & Hildebrandt, 2007).
- Australian workers (9 hours 24 minutes) sat for up to 6 hours longer per day than mothers (3 hours 30 minutes) according to Brown et al 2003. However, the data were collected using different questionnaires.
- In the United Kingdom EPIC study, men on average watched 3 hours and 2 minutes of TV per day and women on average watched 3 hours and 7 minutes of TV per day (Jakes et al 2003).
- In an Australian workplace, the average worker sat for 9.4 hours per day, with work sitting accounting for just over half of the average weekday sitting time (4.9 hours per day). Time spent watching TV or using a computer at home (1.94 hours per day) accounted for just over one-fifth of total sitting time on weekdays, and average time spent during travel was 1.2 hours per day (Miller & Brown, 2004).

1.6 Perceptions of sedentary behaviour and physical inactivity

1.6.1 Barriers, enjoyment and preference for sedentary behaviour – international data only

Few studies look at why people are sedentary, although there are many that investigate why people are physically inactive/active. Because these are discrete behaviours, the barriers and facilitators for sedentary behaviour are unlikely to be the same as those for being physically inactive/active.

A large postal survey of Australian adults assessed sedentary behaviour using a nine-item checklist for the past seven days also asked participants about barriers, enjoyment and preferences (Salmon et al 2003). Sixty-three percent of participants reported enjoyment of sedentary behaviours. Using multivariate logistic regression, the variables that predicted high participation in TV viewing were: enjoyment of TV viewing, "financial cost of being physically active", work commitments and the weather. High enjoyment of reading and the "financial cost of being physically active" were significantly associated with reading more than 5 hours per week. Work commitments and "family needs as a barrier to physical activity" were associated with reading less than 5 hours per week.

For overall leisure time sedentary behaviour the variables that predicted high levels of sedentary behaviour were the "weather as a barrier to physical activity", "financial cost as a barrier to physical activity", and "feeling tired as a barrier to physical activity". Family commitments and work commitments reduced the likelihood of high participation in leisure-time sedentary behaviours. Participation in sedentary behaviour does appear to be related to physical activity barriers, though the authors did not probe sedentary issues separately. The authors concluded by pointing out the importance of both individual and environmental constructs for any planned interventions (Salmon et al 2003).

1.6.2 New Zealand data on barriers to physical activity

There is something of a paradox in data collected about barriers to being physically active. A recent survey (the 2003 Obstacles to Action survey funded by SPARC and the Cancer Society) looked at barriers to being regularly active. Interestingly, the main barriers were a lack of time and being too busy due to work. Given New Zealanders spend, on average, over 3 hours per day watching TV as either a primary or secondary activity, and most adults spend considerable time each day traveling in public or private motorised transport, this seems paradoxical. One of the reasons people appear to have "no time" is that they use so much time to watch TV.

2. Review process

2.1 Goal of the Scientific Committee

The goal of the Scientific Committee is to provide New Zealand nutrition and physical activity practitioners with practical evidence summaries about issues of interest to Agencies for Nutrition Action (ANA) member organisations.

2.2 Topic identification

This topic was identified by the Scientific Committee in consultation with the Chair and the Executive Director of ANA. Three potential topics were identified, and each was investigated by a Scientific Committee member using a rapid scan of the potential literature and by talking with key agencies about the usefulness of the topic area. The proposed topic was considered to be relevant to ANA and its member organisations, and to reflect the professional expertise of members of the Scientific Committee, if it had sufficient, relevant literature that had not been reviewed elsewhere and was of interest to key agencies. Discussion was also held with the Ministry of Health, SPARC, the Health Sponsorship Council and other agencies about suitable topics, and this topic was endorsed.

2.3 Literature review process

A full description is presented in Appendix 1.

3. Current reviews of sedentary behaviour

There are a number of recent review papers relevant to this literature review. These are shown as an annotated bibliography in Table 2. This literature review is not designed to repeat these reviews but to synthesise them, update the findings and make New Zealand-relevant recommendations. They should be seen as valuable supplemental reading in the context of this review.

For example, the review by Hamilton et al (2007) looks at very detailed physiological aspects of the consequences of sedentary behaviour, which is beyond the scope of the present review. The review by Brown et al (2009) looks at the historical changes in the way we have studied the health consequences of physical activity and sedentary behaviour. Brown et al remind us that some of the original work in the area by Morris and colleagues with cardiovascular disease (CVD) risk and CVD mortality was carried out looking at differences between drivers (long sitting time) and conductors (short sitting time) on London buses in the 1960s. The review by Pate et al (2008) looks in some detail at the changing definition of sedentariness, a theme we have followed closely in this review, and one which has pervaded and confused New Zealand health research and policy over recent years.

Table 2: Abstracts of review articles relating to sedentary behaviour

Author	Title	Abstract/introduction
(Booth & Chakravarthy, 2002)	Cost and consequences of sedentary living: New battleground for an old enemy	This report itemises the costs and consequences of sedentary living, and provides cost reasons to fight a war on sedentary lifestyles. It begins by explaining that 70% of US adults are sedentary (undertaking no leisure-time physical activity or less than 30 minutes of physical activity per day), and notes how sedentary living increases the risk of many chronic conditions. (Readers should note Booth and Chakravarthy define sedentary behaviour in a different way to this literature review.) Next, the report defines chronic disease and presents data on all chronic health conditions combined, and on several specific chronic health conditions (coronary heart disease, type 2 diabetes, obesity, obesity-related disorders, and the ageing population). It goes on to examine the costs of sedentary living, including mortality costs and economic costs for all chronic health conditions and for sedentary disorders. After asserting the war on chronic health conditions is not being won, it argues for the need to be proactive rather than reactive, and to promote primary prevention. Finally, it discusses weapons to combat sedentary-induced disease (e.g. focusing on cost benefits, promoting advocacy and activism among professionals associated with physical activity in their occupations, and disseminating information to the general public).
(W. J. Brown, Bauman, & Owen, 2009)	Stand up, sit down, keep moving: turning circles in physical activity research?	This review tracks the evidence and associated recommendations and guidelines for optimal levels of physical activity for health benefit. In the 1950s, early epidemiological studies focused on the increased risk of CVD and all-cause mortality associated with sitting at work. The period from the mid-seventies to the turn of the century saw an initial focus on the health benefits of vigorous exercise give way to mounting evidence for the benefits of moderate-intensity physical activity. As daily energy expenditure in most domains of human activity (travel, domestic and occupational work, and leisure) continues to decline, early 21st century

		researchers are starting to turn full circle, with a rekindled interest in the health effects of sedentary behaviour at work, and indeed in the balance between activity and sedentariness in all aspects of daily life. Until the beginning of the 20th century, physical activity was an inevitable part of people's lives; almost all daily endeavours, including hunting and gathering food, required physical exertion. During the 20th century, the balance shifted from active to more sedentary lifestyles, with increasingly prevalent adverse health consequences. Now, at the beginning of the 21st century, most forms of transport and work are automated (and often involve long periods of sitting), and the "non-working" day includes mostly sedentary leisure-time pursuits and light domestic tasks. The reduction in daily activity is clearly illustrated by comparing data from two studies. The first, conducted in 2002, was a study of physical activity in the 15 EU nations. It reported an average energy expenditure of 24 MET hours per week, which equates to less than 1 hour of moderate-intensity activity each day. The second was a study in an Old Order Amish community in Canada, which reported an average energy expenditure of 253 MET hours per week (or almost 10 hours per day of activity) in 2004. In this community, the use of motorised transportation, electricity and modern conveniences is banned, and most people work on farms, tilling the soil with horses, or grow vegetables in family gardens. The lifestyle differences of the participants in these two studies illustrate the drastic reduction in total daily energy expenditure that is now occurring in both developed and developing countries, and which is in turn prompting changes to the ways we think about the behavioural epidemiology of physical activity and sedentary time.
(Clark, et al., 2009)	Validity and reliability of measures of television viewing time and other non-occupational sedentary behaviour of adults: a review	Time spent in non-occupational sedentary behaviours (particularly TV viewing time) is associated with excess adiposity and an increased risk of metabolic disorders among adults. However, there were no reviews of the validity and reliability of assessing these behaviours. This paper aimed to document measures used to assess adults' time spent in leisure-time sedentary behaviours and to review the evidence on their reliability and validity. Medline, CINAHL and PsychINFO databases and reference lists from published papers were searched to identify studies in which leisure-time sedentary behaviours had been measured in adults. Sixty papers reporting measurement of at least one type of leisure-time sedentary behaviour were identified. TV viewing time was the most commonly measured sedentary behaviour. The main method of data collection was by questionnaire. Nine studies examined reliability and three examined validity for the questionnaire method of data collection. Test–retest reliabilities were predominantly moderate to high, but the validity studies reported large differences in correlations of self-completion questionnaire data with the various referent measures used. To strengthen future epidemiological and health behaviour studies, the development of reliable and valid self-report instruments that cover the full range of leisure-time sedentary behaviour was recommended as a priority.
(Hamilton, Hamilton, & Zderic, 2007)	Role of low energy expenditure and sitting in obesity, metabolic syndrome, type 2 diabetes, and cardiovascular	It is not uncommon for people to spend one-half of their waking day sitting, with relatively idle muscles. The other half of the day includes often large volumes of non-exercise physical activity. Given the increasing pace of technological change in domestic, community and workplace environments, modern humans may still not have reached the historical pinnacle of physical inactivity, even in cohorts where people already do not perform exercise. The purpose of the review by Hamilton et al (2007) was to examine the role of sedentary behaviours, especially sitting, on mortality, CVD, type 2 diabetes, metabolic syndrome risk

	disease	factors, and obesity. Recent observational epidemiological studies strongly suggest daily sitting time or low non-exercise activity levels may have a significant direct relationship with each of these medical concerns. There was a need for studies to differentiate between the potentially unique molecular, physiological and clinical effects of too much sitting (inactivity physiology) separate from the responses caused by structured exercise (exercise physiology). In theory, this may be in part because non-exercise activity thermogenesis is generally a much greater component of total energy expenditure than exercise, or because any type of brief, yet frequent, muscular contraction throughout the day may be necessary to short-circuit unhealthy molecular signals causing metabolic diseases. One of the first series of controlled laboratory studies providing translational evidence for a molecular reason to maintain high levels of daily low-intensity and intermittent activity came from examinations of the cellular regulation of skeletal muscle lipoprotein lipase (LPL) (a protein important for controlling plasma triglyceride catabolism, HDL cholesterol, and other metabolic risk factors). Experimentally reducing normal spontaneous standing and ambulatory time had a much greater effect on LPL regulation than adding vigorous exercise training on top of the normal level of non-exercise activity. These studies also found that inactivity initiated unique cellular processes were qualitatively different from the exercise responses. In summary, emerging inactivity physiology studies are beginning to raise a new concern with potentially major clinical and public health significance: the average non-exercising person may become even more metabolically unfit in the coming years if they sit too much, thereby limiting the normally high volume of intermittent non-exercise physical activity in everyday life. Thus, if the inactivity physiology paradigm is proven to be true, the dire concern for the future may rest with growing numbers of people unaware of the potential insidious dangers of sitting too much, and who are not taking advantage of the benefits of maintaining non-exercise activity throughout much of the day.
(Owen, Bauman, & Brown, 2009)	Too much sitting: a novel and important predictor of chronic disease risk?	Research, policy and practice relating to physical activity and population health has focused on increasing the time adults spend doing moderate- to vigorous-intensity activities; 30 minutes a day is generally the target. However, recent evidence from biomarker studies and objective measurement studies (and also from some prospective epidemiological studies) highlights the importance of focusing on the balance of light-intensity activities and sedentary behaviours, particularly the high volumes of time adults in industrialised and developing countries spend sitting in their 15.5 “non-exercise” waking hours. A particular concern for this new research agenda is how to approach reducing or breaking up prolonged sitting time, and how this may relate to increasing light-intensity and moderate- to vigorous-intensity physical activities. Other research opportunities include carrying out studies on how best to promote higher volumes of overall physical activity (light-intensity activities in addition to moderate- to vigorous-intensity activities) in the context of the ubiquitous environmental and social drivers of sitting time in occupational, transportation, recreational and domestic settings. Particular concerns for the exercise science research agenda include identifying why sedentary behaviour and the associated health relationships seem to be particularly strong for women, and examining the effects of interventions for reducing or breaking up sitting time. The issue of too much sitting has challenging implications for future health care practice and will require the development of new kinds of clinical and public health guidelines.

(Pate, O'Neill, & Lobelo, 2008)	The evolving definition of "sedentary"	Learned scholars have associated "sedentary living" with reduced longevity and impaired health for many centuries. Hippocrates wrote extensively about the benefits of exercise for a variety of ailments, including both physical and mental illnesses. Claudius Galenus (Galen), whose writings dominated European medicine for centuries, believed some form of exercise could be used to treat virtually every disease. For the past half century epidemiologists and physiologists have validated the perceptions of the ancient scholars by demonstrating that persons who perform moderate to vigorous physical activity on a regular basis manifest a plethora of physiological benefits and experience reduced risk of chronic disease and premature mortality. Scientists have also reported sedentary behaviour is associated with a variety of health risks. However, most studies have not measured sedentary behaviour or differentiated it from light activity. It seems reasonable, therefore, to ask whether studies to date actually have examined the health implications of sedentary behaviour, or if they have simply defined sedentary as the absence of moderate to vigorous physical activity. Although sedentary, light, moderate and vigorous activities can be estimated via self-report instruments, the recent development of objective systems for measuring physical activity (in particular, accelerometry) now allows researchers to monitor a wide range of intensities of activity, including sedentary and light activity, with considerable precision. The primary purpose of this review was to emphasise the distinction between sedentary behaviour and the absence of moderate-to-vigorous physical activity. The central hypothesis was that researchers rarely measure sedentary behaviour and, therefore, confound efforts to identify the health effects of sedentary and light activity. The authors noted that, despite frequent claims regarding the harmful health effects of sedentariness, investigators have rarely measured sedentary behaviour in direct ways. In the future, investigators should focus as much attention on the lower end of the activity intensity continuum as has traditionally been placed on the higher end of that continuum, if valid conclusions about the independent effects of each activity intensity category are to be made.

Notes: CVD = cardiovascular disease; EU = European Union; HDL = high-density lipoprotein; LPL = lipoprotein lipase; MET hour = One MET hour is the equivalent of the energy expended by the body during one hour of rest.

4. Measurement of Sedentary Behaviour

4.1 Measurement fundamentals and review

In all areas of health research we seek to understand how the following relate to health outcomes:

- the amount, or dose–response, of a behaviour (e.g. physical activity)
- physiological measures (e.g. triglycerides, blood pressure)
- socio-demographic measures (e.g. income level)
- environmental factors (e.g. the number of TVs in a household).

In each case, valid and reliable measurement is important. In the broader field of physical activity and health, measurement of physical activity is important for the credible development of the field. In the absence of an actual measure of human movement, researchers and practitioners have used self-report measures (usually questionnaires or diaries), indirect measures of energy expenditure (usually indirect calorimetry), heart rate monitoring, and motion sensors (predominantly pedometers and accelerometers) to understand human physical activity.

Study design, budget and the research question to be answered have also informed the type of measure used. In the field of physical activity and health, the main weight of evidence for the benefits of physical activity comes from cross-sectional and prospective studies. The vast bulk of these studies rely heavily on self-report measures. Importantly, this method may mean much of the habitual movement we make, including the lower-intensity physical activities that could substitute for sedentary behaviours, may not be reported. There is now evidence that self-report physical activity may under-represent total daily activity by several orders of magnitude (Mackay, Schofield, & Schluter, 2007). In other words, actual light and moderate physical activity are not well measured by self-report instruments and may be underestimated. In contrast, motion sensors such as pedometers and accelerometers may be able to capture movement of any intensity.

Because public policy and health recommendations relating to physical activity are based largely on evidence that does not necessarily reflect actual daily human movement, it is difficult to fully appreciate what we should be recommending to the public about how much and how often they should move. The field is now recognising the benefits of moderate- and vigorous-intensity physical activities, which are promoted through existing guidelines, but with recent advances in measurement of lower-intensity activity we now have a chance to determine actual relationships with sedentary behaviours and whether guidelines are required.

4.2 Measurement tools for sedentary behaviour

4.2.1 Existing tools

Like physical activity measurement, sedentary behaviour measurement has used self-report methods, energy expenditure methods and motion sensors to try to understand the degree to which people move, or do not move. The methods are very similar to those used for physical activity, with some exceptions.

Table 3 shows the sorts of sedentary behaviour measures more often used in contemporary studies to understand the associations between sedentariness and health; Tables 4 to 9 (see section 5) include both cross-sectional and prospective studies. This is an important inclusion, because many of the measurements used have not necessarily been published as stand-alone measurement papers. In other words, to understand the sorts of methods used to assess sedentary behaviour, we must also review not only the studies devoted to measurement issues, but also the literature around sedentary behaviour and health in general.

4.2.2 Self-report measures

Some contemporary physical activity questionnaires have incorporated measures of sitting and leisure-time screen time. The commonly used International Physical Activity Questionnaires, both the Short Form (IPAQ-SF) and Long Form (IPAQ-LF), incorporate measures of sitting time, as has the Behavioural Risk Factor Surveillance System (BRFSS). When determining the quality of a questionnaire, researchers are typically interested in two constructs – reliability and validity.

Reliability refers to the consistency of the measure; that is, do you get the same result on repeat administrations of the instrument? Most of the commonly used measures have reasonable reliability. For example, Rosenberg et al (2008) showed that both forms of the IPAQ have adequate test–retest reliability, and Reis et al (2005) showed the occupational physical activity questionnaire to have adequate test–retest reliability.

Validity refers to the precision of the measure that is used ie can the proposed instrument return results similar to that of a gold-standard instrument? Validations of self-report measures are typically undertaken using convergent validity methods, where the gold-standard (accelerometry using multi-dimensional motion sensors) is compared with self-report measures over the same period of time on the same subjects. As you would expect, sedentary behaviours obtained by self-report typically underestimate the time spent in sedentary behaviours obtained by accelerometery. Rosenberg et al (2008) found a moderate association between an accelerometer measure of sedentary behaviour and the IPAQ-SF ($r = 0.33$) and the IPAQ-LF ($r = 0.34$). Stronger associations have been found with more detailed self-report instruments. For example, Welk et al (2001) found associations ranging from $r = 0.72$ to 0.95 between Tritrac accelerometry and the seven-day physical activity recall instrument.

Taken together, self-report instruments are useful for understanding population levels of sitting and other sedentary behaviours. However, we should be cautious about taking these as the absolute level of these variables because they are likely to underestimate the true values. Future work in this area needs to move beyond analysing the data in terms of simple associations. Bland−Altman (1986) approaches, involving an understanding of how one variable predicts the other, are critical to convergent validity work. As with other self-report behaviour measures in health, the greater the detail collected, the more behaviour reported, but the greater the negative impact on compliance to the questions and costs in administering the survey. It is therefore likely self-report measures will continue to be dominant in this area of research. This is satisfactory as long as researchers understand exactly what is being measured and what it predicts.

Time-use surveys may offer a nice way to gain insight into the types of activities adults engage in. This type of approach has been used to a limited extent in adults to gather data about transport and TV watching and is covered in section 1.5.1 of this review. In physical activity research, Ridley et al (2006) have developed the Multi-media Activity Recall Questionnaire for Children and Adolescents (MARCA). This has potential application to time use in adults, and certainly future use of such a survey in adults would give much insight into how we spend our time, especially in terms of sedentary activities. The development and/or application of such instruments to the adult population is an important step in understanding adult sedentary behaviour.

4.2.3 Energy expenditure measures

Measures of energy expenditure usually require measurement tools that are expensive and typically lab-based, such as indirect calorimetry. There have been a number of studies where the goal has been to understand the energy cost of sedentary or low-level activities. These types of studies are very useful because they inform estimates of the health benefits, especially in terms of weight management. Beyond the laboratory these measures are typically not suitable for measuring free-living activities and have a high cost.

4.2.4 Motion sensors

Motion sensors probably provide the best option across a range of research questions for measuring sedentary behaviours. They are less costly and more portable than energy expenditure methods, and not prone to the recall problems experienced in self-report tools. They are likely to be suitable across a range of ages, from young children to older adults, making comparisons using the same units feasible. There have been several different methods used, as summarised in Table 3. Evidence for the use of different sorts of sensors in contemporary research is outlined below.

Accelerometry

Accelerometers measure acceleration from (usually) hip displacements during motion such as walking and other movements. The common models include Actigraph and Actical, which measure accelerations in a single axis. Other models, such as the Tritrac and R3, use three axes to measure accelerations. Although intuitively triaxial accelerometers would appear to integrate more information than uniaxial accelerometers, there has been little difference noticed in practical physical activity measurement.

Defining activity based on accelerometer counts has been based largely on arbitrary thresholds. Counts below 100 per minute have been deemed to reflect sedentary behaviour. Although this is arbitrary, it has been a useful threshold. At present these remain the most practical and widely available units for measuring low-intensity movements.

The fundamental limitation with accelerometry alone is detecting posture (lying, standing, versus sitting) and changes in posture. This may be possible, but it is likely this would require second-by-second data and algorithms not yet developed to determine these patterns.

Inclinometers

Recently the use of inclinometers has become popular in this field. An inclinometer measures tilt angle. If such a device is attached to the anterior aspect of the upper leg it is able to understand femur angle (see Figure 5 below). This angle can obviously discriminate between standing and sitting. Some models can record real-time standing and sitting, transitions to either, and walking. The inclinometer has shown good reliability and 95% agreement with second-by-second coding of video and inclinometer data (Grant, Ryan, Tigbe, & Granat, 2006). The use of inclinometers has not yet become widespread in this developing field, but as costs are reduced these are likely to become very popular. The units return simple, valid and useful data on sitting, standing and other activities important to understanding sedentary behaviour.

Figure 5: Typical placement of an inclinometer which is able to differentiate standing and sitting time

Multi-site motion sensors

Several researchers have developed complex systems which integrate sensors across various parts of the body to measure the complex behaviours that occur in free-living activity. Usually the aim is to accurately differentiate between several different types of behaviours. Recent examples (see Table 3) include the Remote Mobility Monitoring System (Dalton et al 2007), which uses a sensor attached to the sternum and the thigh to measure posture. Another recent example is by Levine et al (2008), who used a sensor system attached to a complex body harness that measured activity in several different planes. A further example is the IDEAA system, which comprises a series of five sensors linked to a small computer on the waist, which again measures limb and trunk movements and orientation to correctly classify posture and movement (Zhang et al 2003; Welk et al 2007). These systems are the most accurate way to measure and understand human movement of all intensities. However, the cost, availability and user burden make them impractical for anything other than detailed studies with small samples.

Table 3: Measuring sedentary behaviour

Author and year (reference)	Study sample	Measurement tool(s)	Findings (sedentary)	Other findings of interest	Limitations
Self report					
(W. J. Brown, Trost, Bauman, Mummery, & Owen, 2004)	185 women, 161 men; 18−75 years; Australia.	Test−retest reliability of phone-administered surveys: **Active Australia survey (n = 356)** **IPAQ-SF (n = 104)** **PA items in BRFSS (n = 127)** PA items in Australian National Health Survey (n = 122).	% agreement and kappa[4] used to assess reliability of classification of activity status as active, insufficiently active, or sedentary, but no specific report of results for sedentary classification.	% agreement scores for activity status were good for all 4 surveys (60−79%); kappa values ranged from 0.40 to 0.52.	Only 1 day left between assessments. A smaller number of participants for the BRFSS, IPAQ, and Australian National Health Survey than for the Active Australia survey. No report of agreement or kappa values for repeatability of sedentary classification.
(Craig, et al., 2003)	2721 adults in 12 countries (Australia, Brazil, Canada, Finland, Guatemala, Netherlands, Japan, Portugal, South Africa, Sweden, USA, UK)	**8 x IPAQ surveys** Test−retest reliability of 4 x IPAQ-SF, 4 x IPAQ-LF, using either last 7 days or usual week of activity. Criterion: CSA 7164 accelerometer for 7 days in sub-sample. IPAQ-SF and LF includes questions on sitting on	Spearman’s p for sitting time and accelerometer counts < 100/min ranged from 0.07 (Brazil, IPAQ-SF, usual week) to 0.51 (Finland, IPAQ-LF, last 7 days).	Overall, IPAQ surveys produced repeatable data (Spearman’s p clustered around 0.8). Median p for criterion validity was 0.30.	Low and variable associations found for sitting dimension. Use of accelerometer count threshold as criterion for sitting time (potential to misclassify sedentary).

[4] **Kappa Value:** Kappa value is a chance-corrected measure of agreement between pairs of observers. It reflects the degree of agreement for a particular physical finding. In general, a high level of agreement occurs when kappa values are above 0.5. Agreement is poor when kappa values are less than 0.3.

		weekdays and weekend days. IPAQ-LF also assesses sitting for transport.			
(Ekelund, Griffin, & Wareham, 2007)	98 females, 87 males; 20−69 years; workplace employees; Sweden.	**IPAQ-SF** Sedentary measured by frequency and duration of sitting in last 7 days. Sedentary in leisure time assessed by an additional question about average LTPA in last 12 months: sedentary (< 2 hours of activity/week), sporadic MPA (> 2 hours MPA/week), sporadic regular exercise (> 1−2 sessions/week lasting ≥ 30 min), or regular exercise (≥ 3 sessions/week lasting ≥ 30 min). “Insufficiently active” considered as not meeting ACMS/CDC guidelines using PA level calculated from IPAQ PA questions Criterion: Actigraph accelerometry for ≥ 5d, ≥ 600 min/d using 1 min epochs, sedentary = < 100 counts/min.	Accelerometry: 54% of registered time of all participants was sedentary. IPAQ sensitivity to capture insufficiently active participants was 45%. Self-reported sitting time was significantly correlated with sedentary, classified by accelerometry ($r = 0.16$, $p < 0.05$).	IPAQ correctly classified 77% of respondents as sufficiently active.	Homogeneous sample (all employed, higher education and borderline leaner than general population). IPAQ assessed activity accumulated in 10-minute blocks while activity intensity using accelerometer data was sum of all minutes of activity at each intensity level. Limitations of accelerometry as criterion.
(Macera, et al., 2001)	4528 women, 3001 men; 18+ years; USA.	**BRFSS screening question** Participants responding yes to the following considered	25% of participants considered sedentary using screening question but when		No objective criterion used to determine which approach was most accurate; although the LTPA questions were considered by the

		sedentary: "In the past month, other than your regular job, did you do any physical activities or exercises such as running, callisthenics, golf, gardening, or walking for exercise?" **BRFSS LTPA questions** Those not accumulating ≥ 30 min/day of MPA on ≥ 5 d/week or ≥ 20 min/d of VPA on ≥ 3 d/week considered sedentary	responses to specific LTPA questions were considered, only 15% actually reported no LTPA in past week When recommended PA levels were calculated, 20% of those classified as sedentary by the screening question were considered as meeting the guidelines.		authors to be the most accurate depiction of LTPA, it is feasible that the screening question may have actually been most accurate and the LTPA responses were hindered by self-report bias.
(Martínez-González, López-Fontana, Varo, Sánchez-Villegas, & Martinez, 2005)	40 women; 34.3 (7.1) years; all overweight/obese (BMI range 29.83−56.46). Low education level, Spain.	**Spanish PA Questionnaire** Included questions about number of hours spent in sedentary activities on a typical weekday and weekend day (TV watching, sitting in front of a computer, driving, total time sitting, sleeping, sunbathing in summer and winter, going out with friends), indicators of activity at work (standing, housework, work activities more intense than standing), and number of months every year that each activity was performed. Sedentary lifestyle index calculated based on total number of hours spent sitting per week (and corresponding	Mean sedentary lifestyle index was 61.9 (31.4) h/week. Spearman's correlation of sedentary lifestyle index with EE measured by accelerometer was -0.42 (95% CI: 0.65−0.13).	LTPA correlated with accelerometer (p = 0.51, 95% CI: 0.23−0.71)	Homogeneous sample (female, obese, low education, Spanish speaking)

		MET). Compared with accelerometry (RT3) for 3 days in typical week and 2 days in weekend.			
(Matton, et al., 2007)	35 women, 31 men; 48−78 years; Belgium.	**Flemish PA Computerised Questionnaire (FPACQ)** Self-administered survey completed on computer; 2 versions of FPACQ: for retired/unemployed and employed people. 57−90 questions on demographics, occupation (employed only), transport in leisure time, TV/video watching and computer games, home/garden activities, eating, sleeping, MVPA in leisure time, sports participation, and determinants of PA. Validated using accelerometry (RT3) and 7-day diary. Test−retest reliability assessed over 2 weeks.	Accelerometer output was significantly related to time sleeping ($r = 0.51−0.57$, $p < 0.05$), and TV/video watching and computer games ($r = 0.78-0.80$, $p < 0.001$) in men and women. Compared to accelerometry, FPACQ generally underestimated sedentary behaviours Test−retest reliability for sleeping and TV/video/computer game time was high (ICC = 0.76−0.94).		Requires participants to be proficient in computer use.
(Pettee, Ham, Macera, & Ainsworth, 2008)	93 adults; 45.9 (15.4) years; USA.	Reliability of a single questionnaire item to assess time spent watching TV for inclusion in the 2001 BRFSS. Reliability assessed over 1−3	Test−retest reliability of the item was moderate (ICC 0.42 and 0.55 over a 3-week and 1-week	After adjusting for age and sex, TV time was positively associated with BMI, percentage fat, and LPA, and negatively associated with cardio-respiratory fitness	Self-report of TV time. Sedentary measure used 1 item related to TV time only.

		weeks on 4 occasions.	period, respectively).	and MVPA.	
(Prochaska, Sallis, Sarkin, & Calfas, 2000)	305 females, 242 males; 18−29 years; university students, USA.	Factor analysis of 15 PA items from 7-day PA recall, National Health Interview Survey, Youth Risk Behaviour Survey for College Populations, Purposes of Walking Questionnaire, Exercise Stage of Change, and 1 item on number of hours spent watching TV on typical weekday plus weekend day.	TV time did not correlate strongly with any of the other items and was treated as a single item. After controlling for age, TV time was associated with BMI in females only. TV time was negatively associated with VPA and MPA factors		Self-report of PA/sedentary. Sedentary measure used 1 item related to TV time only.
(Reis, Dubose, Ainsworth, Macera, & Yore, 2005)	28 women, 13 men; 20−63 years, USA.	**Occupational Physical Activity Questionnaire (OPAQ)** Interviewer-administered questionnaire consisting of 7 items, including sitting or standing, walking, and heavy labour; total occupational PA score in hr/week and corresponding MET values calculated. Test−retest reliability assessed over 2 weeks, criterion (7-day Actical accelerometry, 7-day occupational PA record), construct (fitness, % body fat), and convergent (BRFSS occupational PA question) validity were assessed.	Correlation for sitting/standing on OPAQ & PA record was r = 0.37. Convergent validity of OPAQ to identify participants who performed mostly sitting/standing, mostly walking, or mostly heavy labour at work was substantial (kappa = 0.71, 95% CI: 0.49−0.94).	2-week test−retest reliability for OPAQ hr/week ranged from ICC = 0.55−0.91. OPAQ walking was related to accelerometer-determined LPA (r = 0.41), MPA (r = 0.41), and total PA (r = 0.44). Correlations between OPAQ and fitness and % body fat were low (r = -0.17 to 0.32)	Small convenience sample. Some participants completed a self-administered PA record and others completed an interviewer-completed record (which may have influenced recall ability).

(Rosenberg, Bull, Marshall, Sallis, & Bauman, 2008)	160 women, 129 men; 35.93 years; UK, USA, Netherlands.	**Sitting items from IPAQ-LF and IPAQ-SF** Test−retest reliability assessed over 3-7 days. Criterion validation using CSA 7164 accelerometer over 7 days: < 100 counts/min considered sedentary. Agreement between high sitting time and classification of being inactive during leisure time (no moderate or vigorous recreational or gardening activities in previous week)	Reliability of sitting time was acceptable for men and women (range 0.40−1.0). Correlations between total sitting and accelerometer-determined sedentary were significant for both IPAQ-LF ($r = 0.33$) and IPAQ-SF ($r = 0.34$). There was no agreement between sitting time and being classified as inactive using LTPA questions.		Use of accelerometer count threshold as criterion for sitting time (potential to misclassify sedentary).
(Welk, Thompson, & Galper, 2001)	13 women, 20 men; 38−57 years; BMI 28.6 and 28.0 kg/m^2 in women and men, respectively; USA.	**7-day PA Recall** Daily time spent sleeping (rest), in MPA, hard PA, and very hard PA reported by participants, and LPA calculated by subtracting reported amounts from 24 hours (PAR1). Adapted version used where sitting was also reported and added to sleeping time to indicate "rest" (PAR2). Validated using 8-day accelerometry (Tritrac).	Correlation between rest category on PAR1 and Tritrac was $r = 0.27$ (ns). No findings specific to "rest" category using PAR2 criteria reported.	Correlation between Tritrac and 7-day PA Recall ranged from $r = 0.72$ to $r = 0.95$.	Self-report of sleeping and sitting were the only measures of sedentary; no specific measurement of other sedentary behaviours.

Energy expenditure					
(W. Brown, Ringuet, Trost, & Jenkins, 2001)	7 females (mothers of children < 5 years); 35.1 (1.7) years; 56.8 (6.6) kg; 166.4 (5.9) cm; Australia.	**Portable indirect calorimetry (Cosmed K4b2)** 15 minutes each of sitting, vacuuming, washing windows, moderate walking, walking with stroller, grocery shopping. 1 < 3 MET considered LPA	VO^2 for sitting = 3.7 (0.43); MET value for sitting = 1.1 (0.12).	Found that household duties were equivalent to MPA, and pushing strollers had higher MET values than Ainsworth's compendium. Argued that "inactive" classification using insufficient formal LTPA or TPA may overestimate levels of inactivity in mothers due to no consideration of household activities.	Small, homogeneous sample.
(Crouter & Bassett Jr, 2008)	24 women, 24 men; 35 (11.4) years; USA	**Actiheart using standardised group calibration values for VO^2** 18 activities split into 3 routines (sedentary/LPA, LTPA, and household activities) of 6 activities and each routine performed by 20 participants. Validated using portable indirect calorimetry (Cosmed K4b2).	VO^2 for lying, computer work, standing, filing papers, washing dishes and washing windows = 0.00 (0.00), 0.01 (0.01), 0.02 (0.01), 0.05 (0.02), 0.08 (0.01), and 0.15 (0.04), respectively. Combined Actiheart activity and HR algorithm for lying, computer work, standing, filing papers, washing dishes and washing windows = 0.00	Mean error (95% prediction intervals) for combined activity and HR algorithm for all activities using standardised group calibration values versus the Cosmed VO^2 was 0.02 kJ/kg/min (-0.17, 0.22 kJ/kg/min).	

			(0.00), 0.02 (0.02), 0.04 (0.03)*, 0.05 (0.04), 0.10 (0.05), and 0.13 (0.04), respectively * Significantly different from Cosmed VO^2.		
(Lanningham-Foster, Nysse, & Levine, 2003)	122 adults over 4 experiments. 2 experiments − driving vs. walking. "Driving": 28 women, 21 men; 40 (1) years; 31 (6) kg/m^2 "Walk to work": 16 women, 16 men; 19−51 years; 28 (6.3) kg/m^2; USA.	**Portable indirect calorimetry (vMax)** "Driving": measured sitting EE for 30 minutes. "Walk to work": measured 2.5 hours of treadmill walking at self-selected pace.	EE was significantly lower for "driving to work" than for "walking to work" (1.09 [0.14] kcal/min vs. 3.62 [0.75] kcal/min, respectively).	Investigated EE from other labour-saving devices in different samples. Combined impact of using domestic mechanisation (driving, washing machine, dishwasher, elevator use) was estimated as 111 kcal/d.	Different participants used for walking and driving experiments. Behaviours used were simulated (i.e. not actually driving or walking to work). Walking to work for 2.5 hours may be unrealistic at a population level, so findings may overestimate negative effect of mechanisation on EE (especially because EE would have increased linearly with time). No standardisation of EE across the different samples by body weight or other measure.
(Levine, Schleusner, & Jensen, 2000)	17 women, 7 men; 38 (11) years; 58% overweight/obese; USA.	**Indirect calorimetry (SensorMedics)** EE measured in laboratory with SensorMedics 229 indirect calorimeter for 60 minutes resting (lying awake) and 20 minutes each of sitting motionless in armchair, sitting and allowed to move (fidget) naturally while remaining sitting, standing motionless,	Mean (s.d.) EE and mean % above resting for activities was as follows: resting – 5.4 (1.5); sitting motionless – 5.6 (1.6), 3.7%; sitting and fidgeting – 8.2 (2.3), 54%; standing motionless – 6.1 (1.7), 13%;		Lab-based activities only. Sedentary measures didn't include TV time, computer time, etc.

		standing and allowed to move (fidget) naturally, and walking on a treadmill at 3 different intensities.	standing while fidgeting – 10.3 (2.9), 94%; walking 1.6 km/h – 13.7 (4.3), 154%; walking 3.2 km/h – 16.4 (5.4), 202%; walking 4.8 km/h – 21.3 (7.9), 292%. Aside from sitting motionless, all activities were significantly different from resting.		
(Levine & Miller, 2007)	14 obese women, 1 obese man; 43 (7.5) years; 32 (2.6) kg/m^2; USA.	**Indirect calorimetry (Columbus)** 20 minutes each of lying motionless; office-chair sitting; standing motionless; walking at 1 mph, 2 mph, 3 mph; and walking at self-selected speed while working.	EE sitting at office chair was 71 (10) kcal/h, standing was 82 (12) kcal/h, walking at self-selected pace and working was 191 (29) kcal/h. Increase in EE for walking and working over sitting was 119 (25) kcal/h.		Small, homogeneous sample of obese adults, mostly females.
(Tsurumi, et al., 2002)	12 women; Japan.	**HR, accelerometry and EMG** HR (Polar Vantage worn at chest), accelerometry (TA-513G triaxial wrist-worn accelerometer) and EMG were validated using VO^2	Correlation coefficients were 0.29, 0.58, and 0.68 for relationships between VO^2 and heart rate, acceleration, and		No standardisation/control for factors influencing HR/EE noted (e.g. subjects not fasted).

		(TEEM100 metabolic analyser) for 4 minutes each of 4 sedentary tasks; 3 involved sitting and touching 2 points on a table alternately at different speeds and distances apart, and 1 was sitting and touching 2 vertical points on a wall.	deltoid EMG, respectively Coefficient of determination when employing multiple regression analysis with acceleration and EMG as independent variables was 0.65.		
Motion sensors					
(Bouten, Westerterp, Verduin, & Janssen, 1994)	11 men; 23.5 (1.8) years; BMI 20.5 (1.9) kg/m^2; Netherlands.	**Triaxial accelerometer** Accelerometer based on 3 orthogonally mounted uniaxial accelerometers. Validation of accelerometry compared with EE for 3 minutes each of sitting relaxed, sitting and writing, sitting with arm work, alternately sitting and standing for 10 seconds each, and treadmill walking at 5 different speeds Criterion: VO^2 calculated using automated respiratory gas analyser (Oxyconbeta).	Correlation coefficients for sedentary ranged from 0.18 for sitting relaxed to 0.57 for sitting with arm working. The most accurate predictor of EE for sedentary activities was the sum of the integrals of absolute accelerometer output from all 3 measurement directions ($r = 0.82$, $p < 0.001$).	When all walking and sedentary activities were considered, a strong linear relationship between EE and accelerometry was found using the integrals of absolute accelerometer output from all 3 measurement directions ($r = 0.95$, $p < 0.001$).	No measurement of free-living activities.
(Dalton, Scanaill, Carew, Lyons, & Olaighin, 2007)	3 women, 3 men; 81.7 (5.1) years; Ireland.	**Remote Mobility Monitoring System** Portable unit including microcontroller board and 2 ADXL203 accelerometers	% difference in sitting and lying time measured by activPAL and portable unit ranged	Overall % difference in measures of time in combined postures of standing and walking was 2.9%.	Small, homogeneous sample (frail elderly).

		(worn at sternum and thigh) to calculate posture (sitting, standing, lying, walking, sit-lying [transition between sitting and lying], undefined) every second. At 15-minute intervals, portable unit transmits mobility data to external server. Accuracy assessed in 1 subject over 11 hours with directly observed mobility recorded at 5-minute intervals, then in 5 subjects over 11 hours each while also wearing the activPAL as the criterion for postural assessment.	from -0.39% to 2.34% for all participants (overall difference 2.31%).		
(Fruin & Rankin, 2004)	*Experiment 1:* 13 men; 18−25 years; body fat % 14.4 (4.4). *Experiment 2:* 10 women, 10 men; 18−35 years; body fat % 18.6 (6.7). USA	**SenseWear Armband** Collects physiological data through multiple sensors (2-axis accelerometer, heat flux sensor, galvanic skin response sensor); SenseWear measures compared with indirect calorimetry (SensorMedics Vmax 229) over 2 experiments. *Experiment 1 (rest and cycle)* 2 resting trials at which 4 x 10-minute measures taken over 3-hour period while subject reclined but remained awake	Mean resting EE estimated by the SenseWear armband did not differ from the mean indirect calorimetry measure (both were 1.3 (0.1) kcal/min $p > 0.65$). Mean measures for each subject provided by the SenseWear armband and indirect calorimetry were significantly correlated ($r = 0.76$, $p < 0.004$). Bland−Altman plot	*Cycle:* No significant difference between SenseWear and indirect calorimetry at any stage of exercise, although measurements were poorly correlated ($r = 0.03−0.12$). *Treadmill:* SenseWear estimate of EE increased with treadmill speed but not incline, significantly overestimated EE of walking with no grade and significantly underestimated EE on the 5% grade.	Laboratory-based experiments only; no free-living activity measured. Sedentary/resting measure was for lying only; no sitting, computer, TV time, etc. was assessed.

		Exercise: cycle ergometer at 60% VO^{2max} for 40 minutes. *Experiment 2 (treadmill):* Treadmill walking for 30 minutes at 3 intensities).	showed good agreement between the two measures for average resting EE (95% LOA = -0.17−0.20 kcal/min). SenseWear estimates from the 2 resting trials had high reliability (r = 0.87−0.94 between days, and r = 0.93 for average of 4 measures within a trial). Agreement between 2 resting trials was high (95% LOA = -0.07−0.10 kcal/min).		
(Godfrey, Culhane, & Lyons, 2007)	3 women, 7 men; 24.9 (1.69) years; Ireland	**activPAL monitor** Validation of activPAL measurement of time spent sitting, standing, and stepping compared with criterion accelerometer-based system (2 Analog Devices ADXL202 attached to sternum and thigh and connected with a data logger, sampling at 50 Hz and data analysed using Matlab software) over 6 hours.	Overall mean (min, max) % differences for time spent sitting, standing, and stepping were 0.06 (0.02, 0.30), 0.50 (0.09, 4.28), and 1.64 (0.34, 3.03), respectively.		Small, homogeneous sample (young able-bodied adults).
(Grant, et al.,	6 females, 4 males; 43 (10.6) years; 1.7	**activPAL monitor**	Inter-device reliability ICC for all		Lab-based activities only. Small convenience sample of university

2006)	(0.1) metres; 73.7 (10.1) kg; Scotland.	Reliability: 3 separate monitors used simultaneously on each participant Validity: video observation of standing, sitting, and walking at self-selected speed, and 6 everyday tasks (randomly allocated from a list of 19 tasks) for 2−9 minutes. Observers coded whether sitting, standing, or walking; results compared with activPAL output using Bland−Altman methods.	activities was > 0.99, with the exception of walking/upright in everyday tasks (ICC = 0.79). Mean % difference between activPAL and observation was -0.27% for time upright, 0.19% for sitting, 1.4% for standing, and -2.0% for walking. Overall agreement for second-by-second analysis of observer and monitor classifications was 95.9%.		workers.
(Levine, Melanson, Westerterp, & Hill, 2001)	6 women, 5 men; 34 (5) years; BMI 23 (3) kg/m^2; USA.	**Non-fidgeting NEAT** NEAT determined as a combination of body position (sit, stand, lie down, transition) derived using inclinometers (Crossbow CXTA02) attached laterally to thigh and trunk. EE calculated using SensorMedics 229 metabolic cart, and body motion quantified using Tracmor triaxial accelerometer worn at the lumbar spine (enabling distinction between standing and walking for	The measurement of non-fidgeting NEAT by accelerometry, EE, and inclinometers accounted for 85% (9) of total NEAT measured in the room calorimeter The intra-class correlation coefficients for calculated non-fidgeting NEAT and whole-room VO^2		Free-living activities not assessed. Small sample.

		inclinometer data). Criterion: VO^2 calculated using whole-room calorimetry **Fidgeting NEAT using accelerometer outputs** Tracmor accelerometer outputs while sitting, standing and lying down.	were 0.86 (95% CI 0.56, 0.96, p = 0.05) Tracmor output for non-ambulatory activities explained approximately 50% of the variance of unaccounted-for total EE.		
(Welk, McClain, Eisenmann, & Wickel, 2007)	17 women, 13 men; 24.9 (6.1) years; BMI 25.9 (5.6) kg/m^2; USA.	**MTI Actigraph and SenseWear Pro II Armband** Validation of monitors (and comparison of 5 accelerometer threshold values for MVPA and 2 equations for SenseWear Armband) in 1 day of free-living activity using IDEEA EE and PA estimates as criterion.	No significant differences found between IDEEA and SenseWear armband measurements of lying, sitting, or standing. All MTI measures (using various thresholds) significantly different from IDEEA for lying and sitting but not standing.	EE estimates from various MTI equations varied considerably Lowest errors in estimation of time spent in PA were found for new SenseWear equation and MTI threshold of 760 counts/min for MVPA.	Small, homogeneous sample.
(Zhang, Werner, Sun, Pi-Sunyer, & Boozer, 2003)	43 women, 33 men; 13−72 years; BMI 24.7 (4.4) kg/m^2. USA	**IDEEA** 5 small sensors attached to the chest, thighs, and feet, and 200 g microcomputer worn on a belt. Analyses include identification of 22 postures (including sitting, standing, reclining, leaning, and lying	Overall average of correct identification of postures was 99%. Reclining was the most difficult group to identify (96%); lying down, sitting, standing, and leaning were all accurate to >	Gaits were correctly identified at an average rate of 98.5%. Average accuracy of speed estimation of walking and running was 100%. Measurement accuracy was not significantly affected by age or sex.	Postural analysis only doesn't allow for EE while seated but moving (e.g. typing).

		down); 5 limb movements, and gait analysis during walking and running, and calculation of duration, frequency and PA intensity. Lab-based testing involved participants holding each posture and limb movement for 10 seconds, and gait analysis testing on a 60-metre track and flight of stairs (48 steps).	99%. Limb movement without locomotion was correctly recognised at average rate of 99%.		
(Zhang, Pi-Sunyer, & Boozer, 2004)	*Mask calorimeter test:* 17 women, 10 men; 33.7 (13.8) years; BMI 24.8 (4.8) kg/m^2. *Respiratory chamber test:* 5 women, 5 men; 32.9 (12.4) years; BMI 26.1 (5.6) kg/m^2. USA.	**IDEEA** 5 small sensors attached to the chest, thighs and feet, and 200 g microcomputer worn on a belt. Validation of IDEEA EE estimation compared with indirect calorimetry (using non-portable mask calorimeter and respiratory chamber calorimeter). Mask test: 4 minutes each of sitting, standing and lying down, and walking and running tests on a level treadmill. Chamber test: 23 hours in chamber including 3 exercise sessions of walking or running	*Mask test:* Overall accuracy was 98.9 (6.0)%. Accuracy was not significantly affected by age, BMI, weight, or height, but was significantly lower in men than women. *Chamber test:* Overall accuracy was 95.1 (2.3)%. Accuracy was not significantly affected by sex, BMI, time of day, weight or height.		No results reported specifically related to sedentary behaviours. EE from arm movements not assessed with IDEEA

Notes: BMI = Body Mass Index; BRFSS = Behavioural Risk Factor Surveillance System; CI = confidence interval; EE = Energy Expenditure; EMG = Electromyogram; HR = Heart Rate; ICC = Intraclass Correlation ; IDEEA = Intelligent Device for Energy Expenditure and Activity; IPAQ = International Physical Activity Questionnaire ; IPAQ-LF = International Physical Activity Questionnaire – Long Form; IPAQ-SF = International Physical Activity Questionnaire – Short Form; LOA = Low Occupational Activity ; LPA = Low Physical Activity ; LTPA =Leisure Time Physical Activity; MET = Metabolic Equivalent; MPA =Moderate Physical Activity; MTI = Manufacturing Technology Inc Actigraph ; MVPA = Moderate to Vigorous Physical Activity; NEAT = Non Exercise Activity Thermogenesis; OPAQ = Occupational Physical Activity Questionnaire; n.s. = non significant; p = Probability ; PA = Physical Activity ; r = correlation coefficient; TPA = Total Physical Activity; TV =Television ; VO^2 = Oxygen Uptake ; VPA = Vigorous Physical Activity .

5. Associations between sedentary behaviour and health

A primary aim of this review is to identify the evidence for associations between sedentary behaviour and various health risks and health outcomes. Based on an assessment of the studies that provided evidence about associations, the Scientific Committee decided how these studies would be aggregated to provide a logical description of the evidence. These decisions were relatively arbitrary, and the authors acknowledge there is considerable overlap across some categories. For example, we have a category for the broad group of health risks called “metabolic syndrome”, and we also have categories for obesity and for diabetes. We have, however, sought to make these categories on the basis of sensible groupings of the evidence available: obesity, metabolic syndrome, diabetes, cardiovascular disease and cancer. Tables 4 to 9 summarise our findings from this review. Appendix 3 provides a more extensive summary of these papers in annotated bibliography form.

In many of the studies we reviewed there were often weak associations or no association observed between the sedentary behaviours and health risks/outcomes, either for the entire sample or for sub-populations. We caution against the over-interpretation of these results. First, the field is only in its infancy and there is a lack of consistent and strong evidence to draw convincing evidence across a range of domains. Absence of evidence, however, does not necessarily indicate the absence of an effect. The lack of association or weak association may be due to a number of factors, which may reduce the detection of effects. Such factors include small sample sizes (especially for sub-populations underpowered to detect effects), homogeneity within samples, weak measures of sedentary behaviours and often only in one domain (e.g. TV watching), and arbitrary categorisation of both dependent and independent variables.

Despite the limitations of current research, this literature review shows there is evidence that sedentary behaviour may adversely affect health and health risk. The studies are mainly cross-sectional, with a number of prospective studies emerging only recently, reducing the ability to infer causation. Overall, however, there are still only a few studies. Perhaps the most convincing recent study is the 14-year follow-up of nearly 20,000 Canadians in the Canadian Fitness Survey (Katzmarzyk et al 2009). In this study participants self-reported their sitting time into one of five categories. Increasing sitting time was associated with higher all-cause death, CVD death, but not cancer death. These effects persisted independently of physical activity measures. This is the first prospective study (a study that follows people over time to see if ill health results from earlier behaviours), which uses a sample representative of a general population and has measured a very important long-term outcome − death.

Two large US prospective studies (the Nurses’ Health Study and the Health Professionals’ Follow-up Study) investigated the impact of both physical activity and various sedentary measures on a range of health outcomes. Both studies show evidence that TV viewing and increasing sitting time are associated with increased risk of obesity

(Hu et al 2003) and diabetes (Hu et al 2001, 2003) and gallstones (Leitzmann et al 1998; 1999).

5.1 Obesity

Among 50 studies, 38 (29 cross-sectional and nine prospective) reported significant positive associations between sedentary behaviour and obesity, and 12 reported no association (10 cross-sectional and two prospective). Zero studies showed a negative association (see Table 4). Overall, there was considerable evidence that sedentary behaviour is associated with increased weight in adults. It is almost certain sedentary behaviour has no positive health outcomes related to weight. Studies have typically been focused on TV viewing as the measure of sedentary behaviour. About 2 hours per day is the point at which associations start to be identified, but with considerable variation in measurement and analyses. Several studies have showed a positive association between TV and weight, independent of physical activity levels (e.g. Ching et al 1996; Giles-Corti et al 2003; Healy et al 2008a; Liebman et al 2003). Other studies of more than 4 hours of TV per day have shown associations with increased obesity risk (Sidney et al 1996; Vioque et al 2000). For example, Sidney et al reported TV viewing of more than 4 hours per day was associated with odds ratios for being obese ranging from 1.5 to 2.3 across race and sex groups. Vioque et al reported the odds of being obese were 30% higher for each additional hour spent watching TV per day.

The sedentary−weight association has been considered using a range of sitting measures. Self-reported occupational sitting was associated with increased obesity risk in Australian males but not in females (Mummery et al 2005) and leisure-time sitting was associated with overweight by Proper et al (2007). Schmidt et al (2008) also found differential associations by sex: in males, TV viewing was not associated with weight but sitting was; in females the opposite was shown, whereby TV was associated with weight but sitting was not.

Others have considered weight gain prevention. For example, Ball et al (2002) showed Australian females with a moderate to high amount of sitting were less likely to maintain weight at four years' follow-up (OR: 0.80; 95% CI: 0.70−0.91). Blanck et al (2007) found females were less likely to gain weight if non-sedentary, but this effect was only observed for normal-weight people. Brown et al (2005) also observed weight gain in females with increased sitting time: women after five years who sat more than 4.5 hours per day were more likely to gain over 5 kg during that period.

A number of studies found males show less evidence of an association than females when TV time is considered. The opposite is observed for total sitting time and occupational sitting time, where males seem more likely to show an effect than females. This could be because of variability between different measures of sedentary behaviour. For example, TV habits (but not occupation and total sitting time) may have been more homogeneous and less variable among males, while the opposite may be true for females. In other words, an effect was detected in females because they had sufficient variation in TV watching as a group to detect these differences. The same logic applies to occupational and total sitting time, with males having more variation, making the detection of an effect more likely.

Taken together there is considerable evidence sedentary time is associated with increased risk of obesity *per se*, and weight gain in lean people. At this stage more robust measurement and consistency of measurement across studies is required. There is, however, enough evidence both in terms of plausible mechanisms and epidemiological evidence to alert the public to the risks of high TV time, occupational sitting, and high sedentariness in general. The best places, target audiences, intervention audiences and mix of messages/actions for making specific recommendations about TV time and sitting are not yet known.

Table 4: Summary of obesity studies and sedentary behaviour

Type of study	**Direction of association**			
	Positive	**None**	**Negative**	**Total**
Cross-sectional	29	10	0	39
Reference	Bowman 2006; Cameron et al 2003; Ching et al 1996; Crawford et al 1999; Dunstan et al 2005; Fitzgerald et al 1997; Giles-Corti et al 2003; Gortmaker et al 1990; Healy, Wijndaele et al 2008b; Healy, Dunstan, Salmon, Shaw et al 2008a; Healy, Dunstan, Salmon, Cerin et al 2008c; Jakes et al 2003; Jeffery 1998; Kronenberg et al 2000; Leite and Nicolosi 2006; Liebman et al 2003; Martinez-Gonazalez et al 1999; Mummery et al 2005; Oppert et al 2006; Prochaska et al 2000; Proper et al 2007; Rosmond 1996 Salmon et al 2000; Schaller et al 2005; Shields and Tremblay 2008; Sidney et al 1996; Tucker and Friedman 1989; Tucker and Bagwell 1991; Vioque et al 2000)	Brown et al 2003; Crawford et al 1999; Fitzgerald et al 1997; Fotheringham et al 2000; Gao et al 2007; Jeffery 1998; Leite and Nicolosi 2006; Mummery et al 2005; Oppert et al 2006; Prochaska et al 2000		
Prospective	9	2	0	11
Reference	Ball et al 2002; Blanck et al 2007;	Coakley et al 1998; Crawford		

	Boone et al 2007; Brown et al 2005; Ching et al 1996; Coakley et al 1998; Hu et al 2001; Hu et al 2003; Jeffery 1998	et al 1999		
Intervention	0	0	0	0
Reference				
Total	**38**	**12**	**0**	**50**

5.2 Metabolic syndrome

Nineteen cross-sectional studies examining the association between sedentary behaviour and metabolic syndrome were reviewed. Of the 19, 14 reported significant positive associations between sedentary behaviour and metabolic syndrome, with the remaining five studies reporting no association. Zero studies showed a negative association. There were no prospective or intervention studies (see Table 5). As can be seen, there is a modest number of cross-sectional studies that assess the association between sedentary behaviour and metabolic syndrome.

The extent to which metabolic syndrome exists as a stand-alone diagnosis, or simply as a collection of risk factors, is hotly debated in the health and preventive medicine field. There are plausible physiological mechanisms for chronic inflammation and hyperlipidaemia through high levels of sedentariness (Hamilton et al 2007), and evidence (above) for the increased risk of obesity, which are together likely to increase metabolic syndrome risk. Further cross-sectional work in Australia by Dunstan and colleagues has demonstrated an association between sedentary behaviour and various metabolic syndrome measures (Dunstan, et al., 2002), 2005; Healy et al 2007, 2008a 2008b 2008c). Taken together, though, we have only a limited amount of epidemiological evidence confined to cross-sectional studies, so it is premature to discuss the magnitude of these effects.

Table 5: Summary of metabolic syndrome studies and sedentary behaviour

Type of study	**Direction of association**			
	Positive	**None**	**Negative**	**Total**
Cross-sectional	14	5	0	19
Reference number	Bertrais et al 2005; Chang et al 2008; Dunstan et al 2004, 2005, 2007; Gao et al 2007; Healy et al 2007; Healy, Wijndaele et al 2008a; Healy, Dunstan, Salmon, Shaw et al 2008b; Healy, Dunstan, Salmon, Cerin et al 2008c; Kronenberg	Bertrais et al 2005; Conus et al 2004; Dunstan et al 2004; Ekelund et al 2007; Ford et al 2005		

	et al 2000; Li et al 2007; Pietroiusti et al 2007; Schmidt et al 2008			
Prospective	0	0	0	0
Reference number				
Intervention	0	0	0	0
Reference number				
Total	**14**	**5**	**0**	**19**

5.3 Diabetes

Three of 3 studies (1 cross-sectional, 2 prospective) reported significant positive associations between sedentary behaviour and diabetes. Zero studies reported no association and zero studies showed a negative association. There were no intervention studies (Table 7).

There are few studies looking directly at diabetes incidence and sedentary behaviour. However, there are two large prospective studies (Hu et al., 2001; Hu et al., 2003) that identify diabetes as an outcome positively associated with increased sitting. More work needs to be carried out, but we can conclude that there is some evidence for this link.

Table 6: Summary of diabetes studies and sedentary behaviour

Type of study	**Direction of association**			
	Positive	**None**	**Negative**	**Total**
Cross-sectional	1	0	0	1
Reference number	Dunstan et al 2004			
Prospective	2	0	0	2
Reference number	Hu et al 2001, 2003			
Intervention	0	0	0	0
Reference number				
Total	**3**	**0**	**0**	**3**

5.4 Cardiovascular disease and dyslipidaemia

Four of four studies (two cross-sectional and two prospective) reported significant positive associations between sedentary behaviour and cardiovascular disease and dyslipidaemia. Zero studies reported no association and zero studies showed a negative association. There were no intervention studies (see Table 7).

As discussed earlier, the prospective Canadian Fitness Survey study shows the best evidence yet for a link between sitting and cardiovascular mortality (Katzmarzyk et al 2009). In this study, the risk of cardiovascular disease (CVD) progressively increased across higher levels of sitting time. The risk of CVD was 1.54 times higher in those who sat the most compared to those who sat the least. Beyond this, Fung et al (2000) identified an association between sedentariness and hyperlipidaemia in the Health Professionals' Follow-up Study cohort. This association was independent of physical activity. Although only a few studies have been done, there is some evidence that sedentary behaviour is an independent risk factor for cardiovascular disease.

Table 7: Summary of cardiovascular disease/dyslipidaemia studies and sedentary behaviour

Type of study	**Direction of association**			
	Positive	**None**	**Negative**	**Total**
Cross-sectional	2	0	0	2
Reference number	Jakes et al 2003; Schmidt et al 2008			
Prospective	2	0	0	2
Reference number	Fung et al 2000; Katzmarzyk et al 2009			
Intervention	0	0	0	0
Reference number				
Total	**4**	**0**	**0**	**4**

5.5 Cancer

On balance, the evidence for sedentariness causing cancer is limited. There are six studies with equivocal results (see Table 8). However, we should remember that there are a number of forms of cancer, each with multiple risk factors. This, combined with different measurement techniques for sedentary behaviour and the limited number of studies, means more evidence is needed before drawing conclusions or making public health recommendations for cancer risk reduction. Certainly there is a plausible link, with some prospective evidence for some cancers at this stage.

The most convincing evidence is from Howard et al (2008), who looked at colon cancer in 292,069 males and 196,651 females aged 50−71 years from the USA. They found some evidence that high TV viewing (over 9 hours per day) and high sitting (over 9 hours per day) was associated with increased colon cancer incidence. This effect was observed for males and females, but the effect disappeared in multivariate (adjusted) models for females.

Table 8: Summary of cancer studies and sedentary behaviour

Type of study	**Direction of association**			
	Positive	**None**	**Negative**	**Total**
Cross-sectional	0	1	0	1
Reference number		Wolin et al 2007		
Case control	0	1	0	1
Reference number		Zahm et al 1999		

Prospective Reference number	3 Colon cancer males Howard et al 2008; Patel et al 2006; Patel et al 2008	2 Colon cancer females Howard et al 2008; Katzmarzyk et al 2009	0	5
Intervention Reference number	0	0	0	0
Total	**3**	**4**	**0**	**7**

5.6 Back pain, bone health, gallstones and mental health

There has been limited investigation into other outcomes such as back pain, bone health, gallstones and mental health. All of the associations reported are in cross-sectional studies. More research needs to be carried out to draw conclusions about an effect for these outcomes. Results for these are presented in Table 9.

Table 9: Summary of miscellaneous studies and sedentary behaviour

Type of Study	**Direction of association**		
	Positive	**None**	**Negative**
ack pain			
Cross-sectional	2 Spyropoulos et al 2007; Womersley 2006)	0	0
Prospective	0	0	0
Total	***2***	***0***	***0***
Poor bone health	1	0	0
Cross-sectional	Weiss et al 1998	0	0
Prospective	0		
Total	***1***	***0***	***0***
Gallstones			
Cross-sectional	0	0	0
Prospective	2 Leitzmann et al 1998; 1999	0	0
Total	***2***	***0***	***0***
Mental disorders			
Cross-sectional	1 Sanchez-Villegas et al 2008	0	0
Prospective	0	0	0
Total	***1***	***0***	***0***

6. Interventions to decrease sedentary behaviour

The notion of intervening solely to reduce sedentary behaviour in adults is a relatively new concept. Although TV-watching reduction has been a common intervention in children, this seems to have had little translation to working with adults. In the small amount of research available, the stand-out idea and application is Levine's "treadmill desk" concept (McAlpine et al 2007; Thompson et al 2007). In these studies, Levine and colleagues substituted a traditional sit-down desk for a desk that incorporates a low-speed treadmill into its design. Instead of sitting, it is possible to walk at 1−2 km/h while working on office-based tasks, such as talking on the telephone and undertaking computer work. This sort of intervention is rightly targeted to workplaces. Workplace sitting is highly prevalent in most office environments and may therefore be a great place to start interventions. While modest effects were shown in pilot work (Thompson, Foster, Eide, & Levine, 2008), the full feasibility and efficacy of this sort of office environment are not yet well understood. There are other options for breaking sitting time in workplaces, such as using height-adjustable desks (Schofield, Kilding, Freese, Alison, & White, 2008). However, like treadmill desks, much more work needs to be carried out to understand the possible health benefits associated with extra standing and therefore reduced sitting time.

It is also likely that interventions used to increase habitual light and moderate physical activity, such as pedometer-based interventions, will encourage people to decrease sedentary time. Many of these types of programmes have been run in a variety of settings, with effective results in terms of increasing overall physical activity and decreasing a range of health risk factors, including weight (e.g. Sidman et al 2004). Few have looked specifically at sitting and other sedentary behaviours, but those that have included a community-setting approach (De Cocker et al 2008). Incorporating the 10,000 Steps approach in Belgium saw a 30-minute differential in sitting time at follow-up in the intervention community compared to the control communities. However, the long-term efficacy of these programmes for sustaining behaviour change is unknown.

We have reviewed a number of studies that purport to be sedentary behaviour interventions, and many of these are included in Table 10. The main issue is that while these people sit for long periods, this is not an outcome measure. This sort of research dominates the academic literature in physical activity and health. It is important that as we start to understand the importance of both physical activity and sedentary behaviour as separate constructs, we measure both at baseline and at the end of the intervention study. We would suggest there are already a large number of successful physical activity initiatives out in communities, workplaces, schools and other settings that are effective at both increasing physical activity and reducing sedentary behaviour. The problem is we have simply not assessed the sedentary outcomes to know this.

Table 10: Interventions to decrease sedentary behaviour

Author, year **(reference)**	**Study sample**	**Assessment of sedentary behaviour**	**Assessment of outcome**	**Intervention description**	**Confounders adjusted for / limitations**	**Main outcomes**
(De Cocker, De Bourdeaudhuij, Brown, & Cardon, 2008)	866 community residents (440 intervention, 426 control); 25−75 years; Belgium	No sedentary inclusion criteria applied; measures of sitting time taken. Self-report of daily sitting time and transport-related sitting time gathered	IPAQ-LF, pedometer steps (Yamax SW-200); daily activity log for 7 days.	Mass media campaign using street signs, press conferences, advertisements, sale and loan of pedometers, website use, workplace projects, health professionals, schools, businesses Media messages promoting 10,000 steps per day, 30 minutes per day MPA on ≥ 5 days or 20 minutes VPA 3 times per week.	*Confounders adjusted for* Age, education level. *Limitations* Self-report for sitting time. No actual measure of SES used. No consideration of employment status, type of work, BMI, or specific sitting behaviours.	Intervention community decreased daily total sitting time by 12 minutes compared with an increase of 18 minutes per day in control community ($p = 0.002$) In the intervention community, total daily sitting time decreased more in participants who increased step counts (-18 minutes per day, $p = 0.012$) than those who did not (no change, n.s.)
(Cramp & Brawley, 2006)	57 “primarily sedentary” postnatal women; 20−46 years; USA.	Defined as “primarily sedentary” if reported less than a daily accumulation of mild to moderate PA on 2 or fewer days per week for the past 6 months.	Self-reported PA (7 days PAR), barrier efficacy and proximal outcome expectations.	Participants randomised to receive either 4-week standard care postnatal exercise programme or 4-week standard treatment plus 6 group-mediated cognitive behavioural intervention sessions and 4-week home-based self-structured exercise.	*Confounders adjusted for* Age, marital status, number of children, average month babies were born, breast-feeding and bottle-feeding status *Limitations*	Significant treatment effects in frequency and volume of PA over intensive and home-based phases compared with standard treatment ($p < 0.01$). Enhanced intervention increased in barrier efficacy and outcome expectations, and standard care group

					Self-report for outcome measure No crossover of treatment conditions conducted.	decreased ($p < 0.05$).
(Dunstan, et al., 2006)	27 sedentary women, 30 sedentary men; overweight with type 2 diabetes; 40−80 years.	Categorised sedentary if no strength training and < 150 minutes brisk walking or moderate exercise per week in the preceding 6 months.	Glycaemic control (HbA_{1c} [A1C]).	15-month trial with 2 phases: 1. introductory: 2-month lab-supervised resistance programme 2. maintenance: randomised to either centre-based or home-based resistance training 2−3 times per week for 12 months, including monthly telephone calls. Assessments at baseline, 2 months and 14 months.	*Confounders adjusted for* Age, sex, duration of diabetes. *Limitations* No non-treatment control group. Self-report measure used for adherence in home-based participants. No assessment of change in PA/sedentary for all participants. No standardisation of exercise regimes.	No significant difference in glycaemic control (A1C) change between groups. Glycaemic control significantly improved in all participants after 2 months lab-supervised programme and in centre group after 12-month maintenance programme. Adherence to exercise prescription was 68.1 (25.0) and 67.1 (27.1)% in the centre- and home-based groups, respectively.
(Fidler, et al., 2008)	2 radiologists; USA	No sedentary measure.	Ability to reinterpret 100 clinical computed tomographic examinations while walking at	Test of feasibility of using walking workstations when computing tomographic examinations.	*Confounders adjusted for* Not stated. *Limitations*	For reviewer 1, the mean detection rates were 99% for walking & 88.9% for conventional interpretations ($p = 0.0003$).

			1 mph on a walking workstation (using a treadmill).	Comparison of results derived when on walking workstation with those computed over 1 year previously; 10 cases reviewed per session.	2 participants, relevant to radiology only.	For reviewer 2, the mean detection rates were 99.1% for walking & 81.3% for conventional interpretations (p < 0.0001).
(Finkenberg & et al., 1976)	384 sedentary males; 30−59 years; USA.	Employment role. Categorised sedentary if employed “in what was deemed a relatively sedentary position>	CHD development (age, serum cholesterol, systolic BP, haemoglobin, relative body weight, smoking, ECG patterns).	Periodic evaluation of cardiopulmonary systems, participant feedback, personal physical fitness programme prescription over 6 years (1968−74).	*Confounders adjusted for* Age (analyses repeated for ages 30−39, 40−49, 50−59). *Limitations* Homogeneous sample; male, likely to be White and high SES, although these weren’t stated (working at NASA). Sedentary categorisation tenuous; no measurement of PA outside workplace. No measurement/ consideration of other PA behaviours,	For each year of participation in the exercise stress test programme, CHD development scores for the control group were significantly greater than those in the intervention group.

					demographics, etc.	
(Haber & Rhodes, 2004)	20 sedentary women, 5 sedentary men; older Caucasian adults; 55−85 years; USA.	Categorised sedentary if self-reported "not currently or recently engaged in an exercise routine performed 2+ times per week" and a belief that "most of one's discretionary time was spent in low-energy activities".	% of success in achieving health contract goals (calculated by dividing number of exercise behaviours reported by participant by number scheduled to be performed).	Health contract and calendar focusing on increasing PA or exercise for 1 month. In-person counselling for goal-setting and contract completion. Telephone assessment after week 1. In-person visit at month end.	*Confounders adjusted for* None *Limitations* Self-report for outcome measure. No longer- term assessment of behaviour change. Small, homogeneous sample. No control group.	80% of participants achieved $\geq$75% of scheduled sessions. 60% of participants achieved 100% of scheduled sessions.
(Kerr & McKenna, 2000)	103 women, 78 men; 38 (10.6) years; England.	Study-specific questionnaire to identify stage of change (TTM). No specific sedentary categorisation, but only those considered pre-contemplators, contemplators or preparers were eligible.	Questionnaire to assess change in knowledge, attitude, self-efficacy, personal values, outcome expectancy and TTM stage of change.	Participants randomly assigned to receive either standard Health Education Authority "Active for Life" campaign or one of four media campaigns (specific to stage of change and received via internal mail): 1. It's fun by foot 2. Walking makes you look good 3. Don't need a dog to look good 4. Walking works.	*Confounders adjusted for* None stated. *Limitations* No actual sedentary or PA measured.	No difference in any outcome measures found.
(McAlpine,	19 sedentary	No specific sedentary	Indirect	No actual intervention	*Confounders*	Stepping increased EE

Manohar, McCrady, Hensrud, & Levine, 2007)	adults; 27 (9) years; 9 lean, 10 (53%) obese; USA.	categorisation stated, but all participants were office workers.	calorimetry (Columbus). Compared EE from 30 minutes lying motionless, 20 minutes office chair sitting, 20 minutes standing motionless, and 15 minutes of treadmill walking at 0.5, 1, 1.5, 2, 2.5, and 2 mph with 15 minutes stepping.	applied; rather, authors introduce under-desk steppers for office workers to use intermittently.	*adjusted for* Body weight (only for increase in EE for obese vs. lean subjects). *Limitations* Small sample, intervention not implemented over prolonged duration; injury potential not considered.	above sitting in an office chair by 289 (102) kcal/h ($p < 0.001$). Increase in EE was greater for obese than lean subjects ($p = 0.03$) only when body weight was not taken into account.
(Richardson, et al., 2007)	20 sedentary women, 10 sedentary men; diabetics 38−71 years; USA.	Categorised sedentary if self-reported less than 150 minutes of MPA at baseline.	BETA version of Omron HJ-720IT pedometer, enabling the recording of steps accumulated in 10-minute bouts only or total steps accumulated (in addition to standard pedometer facilities).	6-week randomised trial of automated Internet-based intervention using uploading-enhanced pedometers, including tailored motivational messages, tips about managing diabetes, automatically calculated goals, and feedback about performance towards goals. Intervention focus was either on increasing total pedometer steps or number of 10-minute bouts of activity (recorded by the pedometer).	*Confounders adjusted for* n/a *Limitations* Small homogeneous sample of diabetic patients. Limited to those with regular email use, access to a computer with Internet, Win 200 or XP operating system, and USB port.	No significant difference between groups; combined, all participants significantly increased average daily bout steps by 1921 (2729) steps ($p < 0.001$), and average daily total steps by 1938 (3298) steps ($p < 0.001$). Compared with 3% at baseline, 40% of participants accumulated > 150 minutes of bout activity during final week of programme. Participant satisfaction and compliance was lower in those receiving the bout-focused intervention.

(Sidman, Corbin, & Le Masurier, 2004)	92 sedentary women; 20−65 years; USA.	Categorised sedentary if scored $\leq$ 4 on ACSM/CDC PA questionnaire (as below): 1. I do not exercise or walk regularly now, and do not intend to start in the near future. 2. I do not exercise or walk regularly, but I have been thinking of starting. 3. I am trying to start to exercise or walk, or I exercise or walk infrequently. 4. I am doing vigorous exercise less than 3 times per week or moderate physical activity less than 5 times per week.	Pedometer steps (Yamax MLS-2000).	Participants classified as low (< 5500/d), medium (< 7000/d) or high steps (> 7000/d) from 7-day baseline data. 3-week intervention, 1 telephone call to set step-based goals; participants randomised to either 10,000-step goal or personal step goal.	*Confounders adjusted for* Baseline steps, treatment week. *Limitations* Participants self-reported outcome (faxed or emailed pedometer steps to researchers weekly). No report of change in status using ACSM/CDC PA criteria.	Women with low baseline steps showed significantly less goal attainment in the 10,000 steps goal group. Step counts increased after goal assignment, but no significant difference between interventions found.
(Strecher, Wang, Derry, Wildenhaus, & Johnson, 2002)	Adults aged 21−70 years who engage in 2 or more of 3 possible risk behaviours: smoking, low vegetable intake, sedentary behaviour.	Categorised sedentary if self-reported exercising less than 4 times per week.	Behaviour change in either smoking, vegetable intake or PA.	Randomised 2 x 2 intervention of computer-based tailored print and tele-counselling interventions. Receive either: generic print messages, tailored print messages, tailored tele-counselling sessions, or tailored print messages + tailored tele-counselling sessions.		No outcomes measured. This was a methods paper only, with no baseline data included.

				4 treatments over 18 weeks: 2 and 4 weeks after baseline, 2 and 4 weeks after 3-month assessment. Baseline, 3-month and 12-month assessments.		
(Thompson, Foster, Eide, & Levine, 2007)8	25 adults; USA.	No sedentary measure taken.	Steps (StepWatch activity monitor) accumulated over workdays (9 am − 4 pm).	Test of walking workstations in office-based jobs (using Pacemaster treadmills). 2 weeks usual work setting (seated), 2 weeks acclimatising to the walking work station, 2 weeks using the walking workstation		Participants increased their steps during work hours from 2200 to 4000 during acclimatisation ($p = 0.01$) and to 4200 during the walking workstation period ($p = 0.03$). Most participants increased their steps between 1.5 and 2 times when the treadmill was available. All subjects walked at least an additional 30 minutes per workday.

Notes: ACSM/CDC = American College of Sports Medicine /Centres for Disease Control; BMI = body mass index; BP = blood pressure; CHD = coronary heart disease; ECG = electrocardiograph; IPAQ =International Physical Activity Questionnaire; MPA = moderate physical activity; n.s. = not significant; PA = physical activity; PAR = physical activity recall; SES = socio-economic status; TTM = Transtheoretical Model; VPA = vigorous physical activity.

7. Recommendations and future work

7.1 Sedentary behaviours need to be addressed

Although this field is still very much in the development stage, there is sufficient evidence to suggest that sedentary behaviour is a distinct risk for multiple health outcomes and that this risk appears to be independent of time spent doing moderate and/or vigorous physical activity. Because of the lack of measurement of sedentary behaviour, there is insufficient evidence to explain the nature of the relationship between sedentary behaviour and multiple health outcomes, and how much sedentary time is acceptable. Therefore, more research is required.

It is important to acknowledge the role that light activity and habitual movement (e.g. slow walking, walking around the house/office) may play in health, and especially in energy expenditure.

We recommend:

1. Research: investigating doses and levels of sedentary behaviour and the resulting disease risk to inform policy decisions and help develop recommendations and guidelines. Evidence gaps are detailed in the section below.

2. Policies and Guidelines: Government agencies such as Ministry of Health, SPARC and Department of Labour consider the role of sedentary behaviour when developing policies and guidelines.

7.2 Disseminating the message

The simple message is to "move more, sit less". Dissemination of this message can occur in a variety of different settings including workplaces, primary care settings, sport and recreation, and public health, as well as the wider community.

7.3 Evidence gaps

At present there are several gaps in the research literature; filling these will provide important evidence for policy and action in this area. Research priorities include:

- Epidemiology: measuring how sedentary New Zealanders are, trends, and which population groups have the highest levels of sedentariness.
- Epidemiology: further detailed epidemiological work, especially prospective studies that incorporate objective measures to understand the health outcomes associated with high levels of sedentary behaviour.
- Physiology: further physiological work investigating the effect of sedentary behaviour on biomedical outcomes related to glucose metabolism and blood lipids. This will build on research already underway and well reviewed by Hamilton et al (2007).
- Environmental influences: investigating the macro and micro(e.g., settings-based)

environmental factors that promote sedentariness.

- Interventions: researching the efficacy of environmental re-engineering to promote standing and ambulatory pursuits, which should be both in the broader urban environment and specific to settings such as workplaces, schools and social settings.

7.4 Intervening across settings

Approaches that involve changing sedentary behaviour in specific settings are likely to be effective. We suggest workplace and family/whānau settings are appropriate places to make improvements.

In the workplace many adults spend long periods of time sitting. We suggest organisations could adopt the following approaches:

- Acknowledge sedentary behaviour is a workplace health and productivity issue and address sedentary behaviour in a systematic way.

- Provide vertical (or height-adjustable) work stations for employees that allow workers to stand for part of the day while continuing to work at computers and other office/factory equipment. Treadmill-based work stations could be considered by workplaces in the future.

- Encourage staff to "walk and talk" where practical, by moving about the workplace when communicating with each other rather than using email, phones and seated meetings.

- Encourage staff with largely sedentary tasks to take breaks that involve movement of some kind.

Home environments are often characterised by long periods of sitting, especially watching electronic media. At the individual and family/whānau levels we suggest the following interventions may be effective in reducing sedentariness:

- Think of movement as an opportunity, not an inconvenience (e.g., park the car a little further away from destinations, view household chores positively as activities that increase energy expenditure).
- Reduce TV viewing and recreational screen time.
- Walk, cycle or use public transport to commute and move about. Minimise car and motorcycle use, and consider car-free days.
- Be active in as many ways as possible. If you fidget, or like to pace while talking on the phone, keep doing so.
- As a family, look for ways to modify your household environment to increase movement and minimise sitting time (e.g., household computer stations could be modified to allow standing at computers).

- Labour-saving devices are not essential household items, manual tasks help to contribute to higher energy expenditure.
- When participating in recreation and hobbies, consider how you can reduce sedentary behaviour associated with that recreation and hobby.
- When socialising with friends, consider options that include movement (e.g., grab a coffee-to-go and walk while you socialise).

Strategies to reduce TV viewing could include the following:[5]

- Have a maximum of one TV per household, or consider not having a TV.
- Move the TV set away from the most-used room in the home.
- Remove TV sets from bedrooms and get rid of excess TVs.
- Place clear limits on how much TV can be viewed in the household.
- Designate certain days of the week to be TV free.
- Plan the TV programmes the family/whānau want to watch at the start of the week and don't watch any others.

[5] These strategies have been added based on a previous ANA report by Scragg et al 2006 *Does TV watching contribute to increased body weight and obesity in children?* The authors believe these recommendations complement those highlighted in the current literature review.

References

Ainsworth B. E., Haskell, W. L., Whitt, M. C., Irwin, M. L., Swartz, A. M., Strath, S. J., et al. (2000). Compendium of physical activities: an update of activity codes and MET intensities. *Medicine & Science in Sports & Exercise, 32*(9 Suppl), S498−504.

Ball, K., Brown, W., & Crawford, D. (2002). Who does not gain weight? Prevalence and predictors of weight maintenance in young women. *International Journal of Obesity & Related Metabolic Disorders: Journal of the International Association for the Study of Obesity, 26*(12), 1570-1578.

Bennett, J. A., Winters-Stone, K., Nail, L. M., & Scherer, J. (2006). Definitions of sedentary in physical-activity-intervention trials: a summary of the literature. *J Aging Phys Act, 14*(4), 456-477.

Bertrais, S., Beyeme-Ondoua, J.-P., Czernichow, S., Galan, P., Hercberg, S., & Oppert, J.-M. (2005). Sedentary behaviors, physical activity, and metabolic syndrome in middle-aged French subjects. *Obesity Research, 13*(5), 936-944.

Blanck, H. M., McCullough, M. L., Patel, A. V., Gillespie, C., Calle, E. E., Cokkinides, V. E., et al. (2007). Sedentary behavior, recreational physical activity, and 7-year weight gain among postmenopausal U.S. women. *Obesity, 15*(6), 1578-1588.

Bland, J. M., Altman, D. G., (1986). Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1 (8476): 307–10.

Boone, J. E., Gordon-Larsen, P., Adair, L. S., & Popkin, B. M. (2007). Screen time and physical activity during adolescence: Longitudinal effects on obesity in young adulthood. *International Journal of Behavioural Nutrition and Physical Activity*.

Booth, F. W., & Chakravarthy, M. V. (2002). Cost and Consequences of Sedentary Living: New Battleground for an Old Enemy. *SO - President's Council on Physical Fitness and Sports Research Digest. Series 3 n16 Mar 2002.*

Bouten, C. V., Westerterp, K. R., Verduin, M., & Janssen, J. D. (1994). Assessment of energy expenditure for physical activity using a triaxial accelerometer. *Medicine & Science in Sports & Exercise, 26*(12), 1516.

Bowman, S. A. (2006). Television-viewing characteristics of adults: correlations to eating practices and overweight and health status. *Prev Chronic Dis, 3*(2), A38.

Brown, W., Ringuet, C., Trost, S. G., & Jenkins, D. (2001). Measurement of energy expenditure of daily tasks among mothers of young children. *Journal of Science & Medicine in Sport, 4*(4), 379-385.

Brown, W. J., Bauman, A. E., & Owen, N. (2009). Stand up, sit down, keep moving: turning circles in physical activity research? *British Medical Journal, 43*(2), 86.

Brown, W. J., Miller, Y. D., & Miller, R. (2003). Sitting time and work patterns as indicators of overweight and obesity in Australian adults. *International Journal of Obesity, 27*(11), 1340-1346.

Brown, W. J., Trost, S. G., Bauman, A., Mummery, K., & Owen, N. (2004). Test-retest reliability of four physical activity measures used in population surveys. *Journal of Science & Medicine in Sport, 7*(2), 205-215.

Brown, W. J., Williams, L., Ford, J. H., Ball, K., & Dobson, A. J. (2005). Identifying the energy gap: magnitude and determinants of 5-year weight gain in midage women. *Obesity research, 13*(8), 1431-1441.

Cameron, A. J., Welborn, T. A., Zimmet, P. Z., Dunstan, D. W., Owen, N., Salmon, J., et al. (2003). Overweight and obesity in Australia: the 1999-2000 Australian Diabetes, Obesity and Lifestyle Study (AusDiab).[see comment][erratum appears in Med J Aust. 2004 Apr 19;180(8):418]. *Medical Journal of Australia, 178*(9), 427-432.

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public health reports, 100*(2), 126.

Chang, P.-C., Li, T.-C., Wu, M.-T., Liu, C.-S., Li, C.-I., Chen, C.-C., et al. (2008). Association between television viewing and the risk of metabolic syndrome in a community-based population. *BMC Public Health, 8*, 193.

Ching, P. L., Willett, W. C., Rimm, E. B., Colditz, G. A., Gortmaker, S. L., & Stampfer, M. J. (1996). Activity level and risk of overweight in male health professionals. *American Journal of Public Health, 86*(1), 25-30.

Clark, B. K., Sugiyama, T., Healy, G. N., Salmon, J., Dunstan, D. W., & Owen, N. (2009). Validity and reliability of measures of television viewing time and other non-occupational sedentary behaviour of adults: a review. *Obesity Reviews, 10*(1), 7-16.

Coakley, E. H., Rimm, E. B., Colditz, G., Kawachi, I., & Willett, W. (1998). Predictors of weight change in men: results from the Health Professionals Follow-up Study. *International Journal of Obesity & Related Metabolic Disorders: Journal of the International Association for the Study of Obesity, 22*(2), 89-96.

Conus, F., Allison, D. B., Rabasa-Lhoret, R., St-Onge, M., St-Pierre, D. H., Tremblay-Lebeau, A., et al. (2004). Metabolic and behavioral characteristics of metabolically obese but normal-weight women. *Journal of Clinical Endocrinology & Metabolism, 89*(10), 5013-5020.

Craig, C. L., Marshall, A. L., Sjöström, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., et al. (2003). International physical activity questionnaire: 12-country reliability and validity. *Medicine & Science in Sports & Exercise, 35*(8), 1381.

Cramp, A. G., & Brawley, L. R. (2006). Moms in motion: A group-mediated cognitive-behavioral physical activity intervention. *Int J Behav Nutr and Phys Act, 3*.

Crawford, D. A., Jeffery, R. W., & French, S. A. (1999). Television viewing, physical inactivity and obesity. *International Journal of Obesity & Related Metabolic Disorders: Journal of the International Association for the Study of Obesity, 23*(4), 437-440.

Crouter, S. E., & Bassett Jr, D. R. (2008). A new 2-regression model for the Actical accelerometer. *British Medical Journal, 42*(3), 217.

Dalton, A. F., Scanaill, C. N., Carew, S., Lyons, D., & Olaighin, G. (2007). *A Clinical Evaluation of a Remote Mobility Monitoring System based on SMS Messaging*.

De Cocker, K. A., De Bourdeaudhuij, I. M., Brown, W. J., & Cardon, G. M. (2008). The effect of a pedometer-based physical activity intervention on sitting time. *Preventive Medicine, 47*(2), 179-181.

Dunstan, D. W., Salmon, J., Healy, G. N., Shaw, J. E., Jolley, D., Zimmet, P. Z., et al. (2007). Association of television viewing with fasting and 2-h postchallenge plasma glucose levels in adults without diagnosed diabetes. *Diabetes Care, 30*(3), 516-522.

Dunstan, D. W., Salmon, J., Owen, N., Armstrong, T., Zimmet, P. Z., Welborn, T. A., et al. (2004). Physical activity and television viewing in relation to risk of undiagnosed abnormal glucose metabolism in adults. *Diabetes Care, 27*(11), 2603-2609.

Dunstan, D. W., Salmon, J., Owen, N., Armstrong, T., Zimmet, P. Z., Welborn, T. A., et al. (2005). Associations of TV viewing and physical activity with the metabolic syndrome in Australian adults. *Diabetologia, 48*(11), 2254-2261.

Dunstan, D. W., Vulikh, E., Owen, N., Jolley, D., Shaw, J., & Zimmet, P. (2006). Community Center–Based Resistance Training for the Maintenance of Glycemic Control in Adults With Type 2 Diabetes. *Diabetes Care, 29*(12), 2586-2591.

Dunstan, D. W., Zimmet, P. Z., Welborn, T. A., Cameron, A. J., Shaw, J., de Courten, M., et al. (2002). The Australian diabetes, obesity and lifestyle study (AusDiab)—methods and response rates. *Diabetes research and clinical practice, 57*(2), 119-129.

Ekelund, U., Griffin, S. J., & Wareham, N. J. (2007). Physical activity and metabolic risk in individuals with a family history of type 2 diabetes. *Diabetes Care, 30*(2), 337-342.

Ekelund, U., Sepp, H., Brage, S., Becker, W., Jakes, R., Hennings, M., et al. (2005). Criterion-related validity of the last 7-day, short form of the International Physical Activity Questionnaire in Swedish adults. *Public Health Nutrition, 9*(2), 258-265.

Fidler, J. L., MacCarty, R. L., Swensen, S. J., Huprich, J. E., Thompson, W. G., Hoskin, T. L., et al. (2008). Feasibility of Using a Walking Workstation During CT Image Interpretation. *Journal of the American College of Radiology, 5*(11), 1130-1136.

Finkenberg, M., & et al. (1976). *The Effect of a Physiological Evaluation Program on Coronary Heart Disease Risk Scores for Sedentary Individuals* (Reports - Research).

Fitzgerald, S. J., Kriska, A. M., Pereira, M. A., & de Courten, M. P. (1997). Associations among physical activity, television watching, and obesity in adult Pima Indians. *Medicine & Science in Sports & Exercise, 29*(7), 910-915.

Ford, E. S., Kohl, H. W., 3rd, Mokdad, A. H., & Ajani, U. A. (2005). Sedentary behavior, physical activity, and the metabolic syndrome among U.S. adults. *Obesity Research, 13*(3), 608-614.

Foster, C., Hillsdon, M., & Thorogood, M. (2005). Interventions for promoting physical activity. Cochrane Database of Systematic Reviews. Issue 1.

Fotheringham, M. J., Wonnacott, R. L., & Owen, N. (2000). Computer use and physical inactivity in young adults: public health perils and potentials of new information technologies. *Annals of Behavioral Medicine, 22*(4), 269-275.

Fruin, M. L., & Rankin, J. W. (2004). Validity of a Multi-Sensor Armband in Estimating Rest and Exercise Energy Expenditure. *Medicine & Science in Sports & Exercise, 36*(6), 1063.

Fung, T. T., Hu, F. B., Yu, J., Chu, N. F., Spiegelman, D., Tofler, G. H., et al. (2000). Leisure-time physical activity, television watching, and plasma biomarkers of obesity and cardiovascular disease risk. *American Journal of Epidemiology, 152*(12), 1171-1178.

Gao, X., Nelson, M. E., & Tucker, K. L. (2007). Television viewing is associated with prevalence of metabolic syndrome in Hispanic elders. *Diabetes Care, 30*(3), 694-700.

Giles-Corti, B., Macintyre, S., Clarkson, J. P., Pikora, T., & Donovan, R. J. (2003). Environmental and lifestyle factors associated with overweight and obesity in Perth, Australia. *American Journal of Health Promotion, 18*(1), 93-102.

Godfrey, A., Culhane, K. M., & Lyons, G. M. (2007). Comparison of the performance of the activPAL™ Professional physical activity logger to a discrete accelerometer-based activity monitor. *Medical Engineering and Physics, 29*(8), 930-934.

Gordon-Larsen, P., Nelson, M. C., & Popkin, B. M. (2004). Longitudinal Physical Activity and Sedentary Behavior Trends: Adolescence to Adulthood. *American Journal of Preventive Medicine Vol 27(4) Nov 2004, 277-283*.

Grant, P. M., Ryan, C. G., Tigbe, W. W., & Granat, M. H. (2006). The validation of a novel activity monitor in the measurement of posture and motion during everyday activities. *British Journal of Sports Medicine, 40*(12), 992-997.

Haber, D., & Rhodes, D. (2004). Health Contract with Sedentary Older Adults. *Gerontologist, 44*(6), 827.

Hamilton, M. T., Hamilton, D. G., & Zderic, T. W. (2007). Role of low energy expenditure and sitting in obesity, metabolic syndrome, type 2 diabetes, and cardiovascular disease. *Diabetes, 56*(11), 2655-2667.

Haskell, W. L., & Lee, I. (2007). Physical activity and public health. Updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation*.

Healy, G. N., Dunstan, D. W., Salmon, J., Cerin, E., Shaw, J. E., Zimmet, P. Z., et al. (2007). Objectively measured light-intensity physical activity is independently associated with 2-h plasma glucose. *Diabetes Care, 30*(6), 1384-1389.

Healy, G. N., Dunstan, D. W., Salmon, J., Shaw, J. E., Zimmet, P. Z., & Owen, N. (2008a). Television time and continuous metabolic risk in physically active adults. *Medicine & Science in Sports & Exercise, 40*(4), 639-645.

Healy, G. N., Wijndaele, K., Dunstan, D. W., Shaw, J. E., Salmon, J., Zimmet, P. Z., et al. (2008b). Objectively measured sedentary time, physical activity, and metabolic risk: the Australian Diabetes, Obesity and Lifestyle Study (AusDiab). *Diabetes Care, 31*(2), 369-371.

Healy, G. N., Dunstan, D. W., Salmon, J., Cerin, E., Shaw, J. E., Zimmet, P. Z., et al. (2008c). Breaks in sedentary time: beneficial associations with metabolic risk. *Diabetes Care, 31*(4), 661-666.

Hill, J. O., Wyatt, H. R., Reed, G. W., & Peters, J. C. (2003). Obesity and the environment: where do we go from here? (Vol. 299, pp. 853-855).

Howard, R. A., Freedman, D. M., Park, Y., Hollenbeck, A., Schatzkin, A., & Leitzmann, M. F. (2008). Physical activity, sedentary behavior, and the risk of colon and rectal cancer in the NIH-AARP Diet and Health Study. *Cancer Causes Control, 19*, 939-953.

Hu, F. B., Leitzmann, M. F., Stampfer, M. J., Colditz, G. A., Willett, W. C., & Rimm, E. B. (2001). Physical activity and television watching in relation to risk for type 2 diabetes mellitus in men. *Archives of Internal Medicine*, *161*(12), 1542-1548.

Hu, F. B., Li, T. Y., Colditz, G. A., Willett, W. C., & Manson, J. E. (2003). Television watching and other sedentary behaviors in relation to risk of obesity and type 2 diabetes mellitus in women.[see comment]. *JAMA*, *289*(14), 1785-1791.

Jakes, R. W., Day, N. E., Khaw, K. T., Luben, R., Oakes, S., Welch, A., et al. (2003). Television viewing and low participation in vigorous recreation are independently associated with obesity and markers of cardiovascular disease risk: EPIC-Norfolk population-based study. *European Journal of Clinical Nutrition*, *57*(9), 1089-1096.

Jans, M. P., Proper, K. I., & Hildebrandt, V. H. (2007). Sedentary behavior in Dutch workers: differences between occupations and business sectors.[see comment]. *American Journal of Preventive Medicine, 33*(6), 450-454.

Jeffery, R. W., & French, S. A. (1998). Epidemic obesity in the United States: are fast foods and television viewing contributing? *American Journal of Public Health*, *88*(2), 277-280.

Katzmarzyk, P. T., Church, T. S., Craig, C. L., & Bouchard, C. (2009). Sitting time and mortality from all causes, cardiovascular disease, and cancer. *Medicine and Science in Sport and Exercise, Epub ahead of print*, 998-1005.

Kerr, J., & McKenna, J. (2000). A randomized control trial of new tailored walking campaigns in an employee sample. *Journal of Health Communication, 5*(3), 265-279.

Kronenberg, F., Pereira, M. A., Schmitz, M. K., Arnett, D. K., Evenson, K. R., Crapo, R. O., et al. (2000). Influence of leisure time physical activity and television watching on atherosclerosis risk factors in the NHLBI Family Heart Study. *Atherosclerosis, 153*(2), 433-443.

Lanningham-Foster, L., Nysse, L. J., & Levine, J. A. (2003). Labor saved, calories lost: the energetic impact of domestic labor-saving devices. *Obesity Research, 11*(10), 1178-1181.

Leite, M. L. C., & Nicolosi, A. (2006). Lifestyle correlates of anthropometric estimates of body adiposity in an Italian middle-aged and elderly population: a covariance analysis. *International Journal of Obesity, 30*(6), 926-934.

Leitzmann, M. F., Giovannucci, E. L., Rimm, E. B., Stampfer, M. J., Spiegelman, D., Wing, A. L., et al. (1998). The relation of physical activity to risk for symptomatic gallstone disease in men. *Annals of Internal Medicine, 128*(6), 417-425.

Leitzmann, M. F., Rimm, E. B., Willett, W. C., Spiegelman, D., Grodstein, F., Stampfer, M. J., et al. (1999). Recreational physical activity and the risk of cholecystectomy in women.[see comment]. *New England Journal of Medicine, 341*(11), 777-784.

Levine, J. A., Lanningham-Foster, L. M., McCrady, S. K., Krizan, A. C., Olson, L. R., Kane, P. H., et al. (2005). Interindividual variation in posture allocation: possible role in human obesity.[see comment]. *Science, 307*(5709), 584-586.

Levine, J. A., McCrady, S. K., Lanningham-Foster, L. M., Kane, P. H., Foster, R. C., & Manohar, C. U. (2008). The role of free-living daily walking in human weight gain and obesity. *Diabetes, 57*(3), 548-554.

Levine, J. A., Melanson, E. L., Westerterp, K. R., & Hill, J. O. (2001). Measurement of the components of nonexercise activity thermogenesis. *American Journal of Physiology-Endocrinology And Metabolism, 281*(4), 670-675.

Levine, J. A., & Miller, J. M. (2007). The energy expenditure of using a "walk-and-work" desk for office workers with obesity. *British Journal of Sports Medicine, 41*(9), 558-561.

Levine, J. A., Schleusner, S. J., & Jensen, M. D. (2000). Energy expenditure of nonexercise activity. *American Journal of Clinical Nutrition, 72*(6), 1451-1454.

Li, C. L., Lin, J. D., Lee, S. J., & Tseng, R. F. (2007). Associations between the metabolic syndrome and its components, watching television and physical activity. *Public Health, 121*, 83-89.

Liebman, M., Pelican, S., Moore, S. A., Holmes, B., Wardlaw, M. K., Melcher, L. M., et al. (2003). Dietary intake, eating behavior, and physical activity-related determinants of high body mass index in rural communities in Wyoming, Montana, and Idaho. *International Journal of Obesity & Related Metabolic Disorders: Journal of the International Association for the Study of Obesity, 27*(6), 684-692.

Macera, C. A., Ham, S. A., Jones, D. A., Kimsey, C. D., Ainsworth, B. E., & Neff, L. J. (2001). Limitations on the use of a single screening question to measure sedentary behavior. *American Journal of Public Health, 91*(12), 2010-2012.

Mackay, L. M., Schofield, G. M., & Schluter, P. J. (2007). Validation of self-report measures of physical activity: A case study using the New Zealand physical activity questionnaire. *Research Quarterly for Exercise &# 38; Sport, 78*(3), 189-196.

Martínez-González, M. A., López-Fontana, C., Varo, J. J., Sánchez-Villegas, A., & Martinez, J. A. (2005). Validation of the Spanish version of the physical activity questionnaire used in the Nurses' Health Study and the Health Professionals' Follow-up Study. *Public Health Nutrition, 8*(07), 920-927.

Martinez-Gonzalez, M. A., Martinez, J. A., Hu, F. B., Gibney, M. J., & Kearney, J. (1999). Physical inactivity, sedentary lifestyle and obesity in the European Union. *International Journal of Obesity & Related Metabolic Disorders: Journal of the International Association for the Study of Obesity, 23*(11), 1192-1201.

Matthews, C. E., Chen, K. Y., Freedson, P. S., Buchowski, M. S., Beech, B. M., Pate, R. R., et al. (2008). Amount of time spent in sedentary behaviors in the United States, 2003-2004. *American Journal of Epidemiology, 167*(7), 875-881.

Matton, L., Wijndaele, K., Duvigneaud, N., Duquet, W., Philippaerts, R., Thomis, M., et al. (2007). Reliability and validity of the Flemish Physical Activity Computerized Questionnaire in adults. *Research Quarterly for Exercise & Sport, 78*(4), 293-306.

McAlpine, D. A., Manohar, C. U., McCrady, S. K., Hensrud, D., & Levine, J. A. (2007). An office-place stepping device to promote workplace physical activity. *British Journal of Sports Medicine, 41*(12), 903.

Miller, R., & Brown, W. (2004). Steps and sitting in a working population. *International Journal of Behavioral Medicine, 11*(4), 219-224.

Ministry of Health. (2009). Healthy Eating - Healthy Action: Oranga Kai - Oranga Pumau. Accessed 31 March 2009 at http://www.moh.govt.nz/healthyeatinghealthyaction.

Moy, K., Scragg, R., McLean, G., & Carr, H. (2006). Metabolic equivalent intensities of culturally-specific physical activities performed by New Zealanders. *New Zealand Medical Journal, 119*(1235).

Mummery, W. K., Schofield, G. M., Steele, R., Eakin, E. G., & Brown, W. J. (2005). Occupational sitting time and overweight and obesity in Australian workers. *American Journal of Preventive Medicine, 29*(2), 91-97.

Oppert, J. M., Kettaneh, A., Borys, J. M., Basdevant, A., Ducimetiere, P., & Charles, M. A. (2006). The relationships between indicators of physical activity, indicators of sedentary behaviour and adiposity in French adults: The FLVS II study. *J Public Health, 14*, 87-93.

Owen, N., Bauman, A., & Brown, W. (2009). Too much sitting: a novel and important predictor of chronic disease risk? *British Journal of Sports Medicine, 43*(2), 81.

Pate, R. R., O'Neill, J. R., & Lobelo, F. (2008). The evolving definition of "sedentary".[see comment]. *Exercise & Sport Sciences Reviews, 36*(4), 173-178.

Patel, A. V., Feigelson, H. S., Talbot, J. T., McCullough, M. L., Rodriguez, C., Patel, R. C., et al. (2008). The role of body weight in the relationship between physical activity and endometrial cancer: results from a large cohort of US women. *International Journal of Cancer, 123*(8), 1877-1882.

Patel, A. V., Rodriguez, C., Pavluck, A. L., Thun, M. J., & Calle, E. E. (2006). Recreational physical activity and sedentary behavior in relation to ovarian cancer risk in a large cohort of US women. *American Journal of Epidemiology, 163*(8), 709-716.

Pettee, K. K., Ham, S. A., Macera, C. A., & Ainsworth, B. E. (2008). The Reliability of a Survey Question on Television Viewing and Associations With Health Risk Factors in US Adults.

Pietroiusti, A., Magrini, A., Coppeta, L., Barone, S., Sed, B., Manuli, G., et al. (2007). Metabolic syndrome among operators using video display units in call centers. [Conference Paper]. *SJWEH, 3*(suppl), 49-53.

Prochaska, J. J., Sallis, J. F., Sarkin, J. A., & Calfas, K. J. (2000). Examination of the factor structure of physical activity behaviors. *Journal of Clinical Epidemiology, 53*(8), 866-874.

Proper, K. I., Cerin, E., Brown, W. J., & Owen, N. (2007). Sitting time and socio-economic differences in overweight and obesity. *International Journal of Obesity, 31*(1), 169-176.

Reis, J. P., Dubose, K. D., Ainsworth, B. E., Macera, C. A., & Yore, M. M. (2005). Reliability and validity of the occupational physical activity questionnaire. *Medicine & Science in Sports & Exercise, 37*(12), 2075-2083.

Richardson, C., Mehari, K., McIntyre, L., Janney, A. W., Fortlage, L. A., Sen, A., et al. (2007). A randomized trial comparing structures and lifestyle goals in an Internet-mediated walking program for people with type 2 diabetes. *Int J Behav Nutr Phys Act, 4*(1), 59.

Rosenberg, D. E., Bull, F. C., Marshall, A. L., Sallis, J. F., & Bauman, A. E. (2008). Assessment of sedentary behavior with the International Physical Activity Questionnaire. *Journal of Physical Activity & Health, 5 Suppl 1*, S30-44.

Salmon, J., Bauman, A., Crawford, D., Timperio, A., & Owen, N. (2000). The association between television viewing and overweight among Australian adults participating in varying levels of leisure-time physical activity. *International Journal of Obesity & Related Metabolic Disorders: Journal of the International Association for the Study of Obesity, 24*(5), 600-606.

Salmon, J., Owen, N., Crawford, D., Bauman, A., & Sallis, J. F. (2003). Physical activity and sedentary behavior: a population-based study of barriers, enjoyment, and preference. *Health Psychology, 22*(2), 178-188.

Sanchez-Villegas, A., Ara, I., GuillÉN-Grima, F., Bes-Rastrollo, M., Varo-Cenarruzabeitia, J. J., & MartÍNez-GonzÁLez, M. A. (2008). Physical Activity, Sedentary Index, and Mental Disorders in the SUN Cohort Study. *Medicine & Science in Sports & Exercise, 40*(5), 827.

Saris, W. H. M., Blair, S. N., van Baak, M. A., Eaton, S. B., Davies, P. S. W., Di Pietro, L., et al. (2003). How much physical activity is enough to prevent unhealthy weight gain?

Outcome of the IASO 1st Stock Conference and consensus statement. *Obesity Reviews, 4*(2), 101-114.
Schaller, N., Seiler, H., Himmerich, S., Karg, G., Gedrich, K., Gunther, W., et al. (2005). Estimated physical activity in Bavaria, Germany, and its implications for obesity risk: Results from the BVS-II Study. *Int J Behav Nutr Physical Activity*.
Schmidt, M. D., Cleland, V. J., Thomson, R. J., Dwyer, T., & Venn, A. J. (2008). A comparison of subjective and objective measures of physical activity and fitness in identifying associations with cardiometabolic risk factors. *Annals of Epidemiology, 18*(5), 378-386.
Schofield, G., Kilding, A., Freese, R., Alison, A., & White, K. (2008). Standing up at work: The feasibility of using height adjustable desks to reduce sedentary behaviour and increase energy expenditure. *Journal of Science and Medicine in Sport, 12*, 17-17.
Shields, M., & Tremblay, M. S. (2008). Sedentary behaviour and obesity. *Health Reports, 19*(2), 19-30.
Sidman, C. L., Corbin, C. B., & Le Masurier, G. (2004). Promoting Physical Activity among Sedentary Women Using Pedometers. *Research Quarterly for Exercise and Sport, 75*(2), 122-129.
Sidney, S., Sternfeld, B., Haskell, W. L., Jacobs, D. R., Jr., Chesney, M. A., & Hulley, S. B. (1996). Television viewing and cardiovascular risk factors in young adults: the CARDIA study. *Annals of Epidemiology, 6*(2), 154-159.
SPARC. (2009). About SPARC. Accessed 31 March 2009 at http://www.sparc.org.nz/about-sparc
Spyropoulos, P., Papathanasiou, G., Georgoudis, G., Chronopoulos, E., Koutis, H., & Koumoutsou, F. (2007). Prevalence of low back pain in greek public office workers. *Pain Physician, 10*(5), 651-659.
Statistics New Zealand. (2009). Time use – time for culture. Accessed 31 March 2009 at http://www.stats.govt.nz/products-and-services/Articles/time-use-time-culture.htm#film.
Strecher, V., Wang, C., Derry, H., Wildenhaus, K., & Johnson, C. (2002). Tailored interventions for multiple risk behaviors. *Health Education Research, 17*(5), 619-626.
Stroebele, N., & de Castro, J. M. (2004). Television viewing is associated with an increase in meal frequency in humans. *Appetite, 42*(1), 111-113.
Taylor, R., Scragg, R., & Quigley, R. (2005). Do sugary drinks contribute to obesity in children. *A reported prepared by the Scientific Committee of the Agencies for Nutrition Action. Retrieved, 20*.
Thompson, W. G., Foster, R., Eide, D., & Levine, J. A. (2007). Feasibility of a walking workstation to increase daily.
Thompson, W. G., Foster, R. C., Eide, D. S., & Levine, J. A. (2008). Feasibility of a walking workstation to increase daily walking. *British Medical Journal, 42*(3), 225.
Tsurumi, K., Itani, T., Tachi, N., Takanishi, T., Suzumura, H., & Takeyama, H. (2002). Estimation of energy expenditure during sedentary work with upper limb movement. *Journal of Occupational Health, 44*(6), 408-413.
Tucker, L. A., & Bagwell, M. (1991). Television viewing and obesity in adult females. *American Journal of Public Health, 81*(7), 908-911.
Tucker, L. A., & Friedman, G. M. (1989). Television viewing and obesity in adult males. *American Journal of Public Health, 79*(4), 516-518.
Vioque, J., Torres, A., & Quiles, J. (2000). Time spent watching television, sleep duration and obesity in adults living in Valencia, Spain. *International Journal of Obesity & Related Metabolic Disorders: Journal of the International Association for the Study of Obesity, 24*(12), 1683-1688.
Weiss, M., Yogev, R., & Dolev, E. (1998). Occupational sitting and low hip mineral density. *Calcified Tissue International, 62*(1), 47-50.

Welk, G. J., McClain, J. J., Eisenmann, J. C., & Wickel, E. E. (2007). Field Validation of the MTI Actigraph and BodyMedia Armband Monitor Using the IDEEA Monitor&ast. *Obesity, 15*(4), 918-928.

Welk, G. J., Thompson, R. W., & Galper, D. I. (2001). A temporal validation of scoring algorithms for the 7-day physical activity recall. *Measurement in Physical Education and Exercise Science, 5*(3), 123-138.

Wolin, K. Y., Colangelo, L. A., Chiu, B. C. H., Ainsworth, B., Chatterton, R., & Gapstur, S. M. (2007). Associations of physical activity, sedentary time, and insulin with percent breast density in Hispanic women. *Journal of Women's Health, 16*(7), 1004-1011.

Womersley, L., & May, S. (2006). Sitting posture of subjects with postural backache. *Journal of Manipulative & Physiological Therapeutics, 29*(3), 213-218.

World Cancer Research Fund. (2007). Food, nutrition and physical activity, and the prevention of cancer: A global perspective. Washington DC: American Institute for Cancer Research.

Zahm, S. H., Hoffman-Goetz, L., Dosemeci, M., Cantor, K. P., & Blair, A. (1999). Occupational physical activity and non-Hodgkin's lymphoma. *Medicine & Science in Sports & Exercise, 31*(4), 566-571.

Zhang, K., Pi-Sunyer, F. X., & Boozer, C. N. (2004). Improving Energy Expenditure Estimation for Physical Activity. *Medicine & Science in Sports & Exercise, 36*(5), 883.

Zhang, K., Werner, P., Sun, M., Pi-Sunyer, F. X., & Boozer, C. N. (2003). Measurement of human daily physical activity. *Obesity, 11*(1), 33-40.

Appendix 1

Literature identification

Initial discussions by the Scientific Committee and the Executive Officer covered the potential questions and issues that should be incorporated into this report. A precise and specific search of the literature was conducted. The search strategy was devised by the Scientific Committee and was conducted on the following electronic databases and websites:

- MEDLINE
- Cochrane Library
- DARE database (includes database of abstracts of reviews of effects, National Health Service economic evaluation database, Health Technology Assessment database)
- Health Development Agency evidence base (now incorporated within the NICE evidence base website)
- Ministry of Health website
- National Health and Medical Research Council (NHMRC) website
- National Institute for Health and Clinical Excellence (NICE) website
- Research Findings Register
- Campbell Collaboration
- Google Scholar.

All databases and websites were searched from January 1996 to 21 November 2008, a range chosen to make the analyses manageable. The search terms and an example strategy are provided at the end of this methods section. Additional searches on key author surnames were also undertaken, using the surnames Levine, Dunstan, Mummery and Brown.

Data handling process

Each member of the Scientific Committee independently reviewed the title and abstract of 310 abstracts identified from the search strategy. The following inclusion criteria were used:

- English language only
- January 1996 to November 2008
- human studies
- all study types, descriptive studies, reviews and opinion pieces
- sedentary behaviour is a focus of the study (not a confounder controlled for)
- sedentary behaviour is measured by a specific measure (i.e. exclude papers where physical activity is measured and those not meeting a guideline are lumped together as sedentary)
- people aged over 18 years

- studies on method and measurement of sedentary behaviour.

Exclusion criteria included:

- studies on non-healthy populations (e.g. those suffering from Prader-Willi syndrome, chronic obstructive pulmonary disease, mental illness, etc)
- studies on populations in developing countries
- people aged under 18 years
- non-English-language studies.

Abstracts were rejected if the intervention included pharmacological components, because these interventions are not within the remit of ANA. Similarly, systematic reviews of interventions promoting physical activity in the general population were excluded if they did not explicitly have prevention of measured sedentary behaviour as a stated objective, or alteration of sedentary behaviours as a component. This ensured the data handling process remained focused on its stated aims and objectives.

Of the 310 article abstracts, 142 were found to be potentially relevant by the members of the Scientific Committee and so these articles were retrieved for further consideration. Due to the extended period of this project, a number of other strategies were used to identify potentially relevant papers while the work was ongoing. Consideration of papers up until April 2009 from reference lists, specific literature searches for papers recommended by colleagues and new research released were rich sources of new information. The initial search strategy was narrow in its year range and a number of relevant papers were therefore not picked up initially. It is good practice to source literature using as many methods as possible, and this was reflected in the extra papers that were included for further consideration using this mix of methods.

Assessment of papers

The initial 142 papers identified by the search strategy, along with the additional (RQ − 11; RB – 24; GS − 21) papers identified by reference lists and other means (a total of 197 papers) were separated into three groups based on the research question addressed by the paper. Scientific Committee members were allocated specific research questions, and relevant groups of papers were sent to each member to critically appraise for relevance and quality. Where a paper was found to be equally relevant to multiple questions, the paper and critical appraisal were shared with the other relevant member(s). There was no blinding of authorship of retrieved papers. Where papers were found not to be relevant, they were discarded.

A critical appraisal form based on the Scientific Advisory Committee’s form used in the breakfast review was used in this review. The original form was based on the NHMRC tools for assessing individual studies and the Health Development Agency tool for assessing reviews and systematic reviews. The appraisal form included questions relating to the type of study, populations studied, methods used, and the strengths and weaknesses of each study type. Each member made their own decisions about whether a document should inform the report or be discarded.

Data were extracted into tables for ease of use, and split by type of study methodology, capturing such information as author, year, subjects, methods (and length of follow-up if appropriate), definitions, confounders adjusted for, and main results.

Writing the report

An initial draft of the report was produced by all three members. Members took specific research questions to write, based on the data abstracted into tables. Drafts of each section and subsequent amendments were circulated among all members, and written and verbal comments (at teleconferences) were incorporated into subsequent drafts. Wording in the final summary statements was informed by the World Cancer Research Fund's evidence judgement criteria and the members' judgement. The words, in order of significance, which have been chosen to reflect the consistency, strength and quality of evidence, and the number of studies for each research question are: considerable, reasonable, possible and insufficient. The report was sent for external review.

All authors contributed to the review process and writing of the report, and all members of the Scientific Committee have final responsibility for the report.

The Scientific Committee acknowledges the following people for the peer review of this report and for providing useful feedback: Maea Hohepa (Researcher, Sport and Recreation NZ), Genevieve Healy (Post doctoral Research Fellow, Cancer Prevention research Centre of School of Population Health, Queensland University) and Ralph Madison, (Acting Programme Leader, Clinical Trials Unit, Auckland University). Finally, thanks to Nikki Chilcott for expertly managing the contract, for her good humour, and for ensuring the authors kept to their deadlines.

Research questions

1. What is the context for sedentary behaviour in the adult population?
2. What is sedentary behaviour and how has it been defined/conceptualised?
3. Is sedentariness prevalent among adults?
4. How is sedentary behaviour measured?
5. What are the associations between adult sedentary behaviours and chronic disease and chronic disease risk (and other social factors/behaviours such as productivity, cognition and food intake)? And what factors or environments encourage or discourage (mediate) sedentary behaviour?
6. What are the associations between adult sedentary behaviours and chronic disease and chronic disease risk (and other social factors/behaviours such as productivity, cognition and food intake)?
7. What interventions/environments are effective in reducing adult sedentary behaviours?

8. What are the recommendations for sitting time and sedentary time for the adult population?

Example search strategy

(1) and (2 or 3 or 4 or 5) and (6)

1. Individual search terms with no Medical subject heading (MeSH):
Sedentary behavio(u)r, or
Sedentariness, or
"Occupational sitting"
"Sitting time", or

2. MeSH and non-MeSH headings related to sedentary behaviour:
Video games (MeSH), or
Television (MeSH), or
"momentary time sampling", or
screen, or
sitting, or
"non exercise activity"
"non exercise activity thermogenesis", or
"non exercise attributable thermogenesis"
sedentary 'in title'
"computer usage"
"computer games"
accelerometer
accelerometry.

3. MeSH 'exercise-type' terms not necessarily related to sedentary behaviour:
Exercise (main subject heading), or
Movement (main subject heading), or
Exertion (main subject heading), or
Recreation (secondary subject heading), or
Motor activity (main subject heading), or
"physical activity", or
Energy metabolism (secondary subject heading) – includes energy expenditure, or
"motorized transportation/transport"

4. Other MeSH terms of interest:
Lifestyle (secondary subject heading), or
Work (secondary subject heading), or
Activities of daily living (secondary subject heading), or
Workplace (secondary subject heading), or
Organization and administration (main subject heading) – includes organizational efficiency, voluntary programs, innovation, etc

5. MeSH outcomes of interest:
Body weight (main subject heading), or
Body weights and measures (main subject headings), or
Cardiovascular diseases (main subject heading), or
Metabolic diseases (main subject heading), or
Diet (secondary subject heading), or
Food habits (main subject heading), or
Psychology applied (main subject heading) – this covers things like efficiency (productivity tracked to this term), time management, absenteeism, etc), or
Cognition (secondary subject heading) – this covers things like comprehension, mental fatigue, learning etc, or
Mental health (secondary subject heading) – psychological wellbeing, or
Stress, and Stress psychological (tertiary subject heading)

6. Other important terms:
Adult (main subject heading)

Appendix 2: Prevalence of sedentary behaviour tables

Author, year (reference)	Study sample	Assessment of sedentary behaviour	Limitations	Prevalence
Cross-sectional studies: physical measure of sedentary behaviour (e.g. use of an accelerometer)				
(Matthews, et al., 2008)	6329 participants from NHANES 2003/2004; USA.	Actigraph accelerometer worn for at least 1 day during all waking hours. Average number of days worn was 5.0, average number of hours per day worn was 13.9. Measured time spent sitting, reclining, lying down – at home, work, school, in transit and during leisure time. Validation study conducted using near gold-standard approach. Covers weekday and weekends.	Large nationwide cross-sectional survey. Measured sedentary behaviour. Controlled for wear time in analysis. 13.9 h average wear time is still lower than average waking time of 15 h/d, so still likely to be an underestimate of sedentary behaviour.	Overall children and adults in the USA spent 54.9% of their waking time or 7.7 h/d, in sedentary behaviours. Adults' sedentariness increased by age bracket, from 7.48 h/d for 20−29 years through to 9.28 h/d for 70−85 years (the most sedentary group). Those aged > 50 years had a sedentary level equal too or higher than adolescent boys or girls. Females were more sedentary than males through youth and adulthood, but beyond 60 years this was reversed (p for interaction < 0.01). Mexican Americans were less sedentary than either Blacks or Whites at all age groups. Media time accounts for about half of the overall time spent in sedentary behaviour by the US population.
(Healy, Wijndaele, et al., 2008)	169 Australian adults (67 men and 102 women); age range 30−87 years, mean age 53.4 years. Without known diabetes.	Accelerometer during waking hours for 7 consecutive days. Data analysed into sedentary (< 100 counts per minute), light (100−1951 counts) and moderate-vigorous (> 1951 counts per minute).	Good-quality study, cross-sectional.	57% of awake time spent sedentary, 39% in light-intensity activity and just 4% in moderate to vigorous activities.
(Ekelund, et al., 2005)	185 Swedish workers (87 males and 98 females) aged 20−69 years.	Accelerometer worn for 7 consecutive days, and self report for sitting time from the International Physical Activity	Non-random population.	Average time spent in sedentary activity was 7 h 0 min for males and 6 h 34 min for females. Self-reported sitting time was 6 h 54 min for males

Author, year (reference)	Study sample	Assessment of sedentary behaviour	Limitations	Prevalence
		Questionnaire.		and females.
(Ekelund, et al., 2007)	258 English patients from 20 general practices (103 males and 155 females). Parental history of type 2 diabetes; aged 30−50 years.	Accelerometer worn over 4 consecutive days during the daytime (except while bathing or during other water activities). Sedentary behaviour defined as < 100 counts/min (authors reflect it is an arbitrary threshold).	Non-random sample; very active individuals removed from study. Participants who did not manage to record at least 500 min/d of activity for at least 3 days were excluded from further analysis.	Average time spent sedentary for males were 7:22 h (+/- 97 min), females 6:69 h (+/- 77min). These data reflect waking hours.
Cross sectional studies: recall method of sedentary behaviour undertaken, interviewer-administered				
(Mummery, Schofield, Steele, Eakin, & Brown, 2005)	1579 Australians full-time employees aged 18+ from telephone sample of households in 2 Queensland communities; 875 males and 704 females.	Participants were asked to recall the number of minutes sitting while at work during a normal working day.	Response rate of 44% with the sample drawn from the phone book. Self-report data subject to social desirability and recall biases.	Mean occupational sitting time was 3 h 19 min for the whole sample (men 3 h 28 min; women 3 h 8 min, $p < 0.05$). 25% sat for > 6 h/d at work. Male workers less than 30 yr reported at least 50 min less sitting time than older age groups. Male professionals (4 h 44 min) sat longer than white-collar workers (3 h 22 min), who sat longer than blue-collar workers (2 h 22 min) ($p < 0.001$). Female professionals (3 h 24 min) and white-collar workers (3 h 28 min) sat longer than blue-collar workers (2 h 46 min) ($p < 0.001$).
(Ford, Kohl, Mokdad, & Ajani, 2005)	Representative sample of 1626 men and women in the USA from the NHANES study 1999/2000.	Interviewer-administered – average amount of time spent watching TV or videos or using a computer outside of work over the last 30 days.	Single-item question for sedentary behaviours.	115 watched TV or videos or used a computer 0 h/d; 16.6% did so for < 1 h/d; 29.3% for 2 h/d; 21.1% for 3 h/d and 21.9% for ≥ 4 h/d.
(Bowman, 2006)	9157 American adults aged 20+ years (47.9% male, 76% White, 11% African-American, 9%	Interviewer-administered 24-hour dietary recall method, collected on two non-consecutive days, 3 to 10 days apart.	Small sample size in smaller racial/ethnic groups doesn't provide enough information for analysis.	TV viewing: 0−1 h: 14.7%, 1−2 h: 26.4%, 2 h+: 58.9%. Normal-weight adults (2.3 h; 95% CI: 2.2−2.4) spent significantly less time

Author, year (reference)	Study sample	Assessment of sedentary behaviour	Limitations	Prevalence
	Hispanic, 4% Other); 49.6% high school or less education. Sample selected from United States Department of Agriculture's Continuing Survey of Food Intakes by Individuals.	Daily self-reported TV/video viewing time, categorised as 0−1 hours, 1−2 hours, 2+ hours.		watching TV than overweight (2.6 h; 95% CI: 2.5−2.7) or obese adults (3.0 h; 95% CI: 2.85−3.15). Percentage of adults who watched > 2 h of TV in the age groups 20−29, 30−39 and 40−49 did not differ significantly between groups. Almost ¾ of adults aged 66 yr or older watched > 2+ h/d. A low level of education and those from low-income households were significantly more likely to watch > 2+ h of TV.
(Salmon, Bauman, Crawford, Timperio, & Owen, 2000)	3392 adults; 54.2% females aged 18−60+; 77.1% born Australian; 45.5% 10 years or less education. Respondents gathered from 1996 state physical activity survey in New South Wales; random selection from White Pages; further random selection of "next birthday" method.	TV time and physical activity levels. Computer-assisted telephone interview with questions on sex, age, country of birth, language spoken at home, education and post code. Questionnaire included physical activity (type, frequency, duration and intensity), TV viewing time, height and weight.		Average time spent watching TV 2.4 h/d (s.d. = 1.4). 12.6% males and 14.3% females watched > 4 h/d. 27.8% males and 27.6% females watched 2.5−4 h/d. 32.8% of highly active people watched > 2.5 h/d. 54% watched 1−2.5 h and 12% watched < 1 h/d.
(Jans, et al., 2007)	7720 Dutch adults (aged 39, s.d. = 11); 60% men; 38% had university education or	Questions about time (min) spent sitting (work, leisure, domestic chores, travel) and supine (in bed) for the 2 days prior (no interviews	Cross-sectional, some self-selection bias (only 50% of participants asked completed the study).	On average, Dutch workers spend 14 h (862 min) per day either sitting or supine: 7 h (423 min) was spent sitting. Evenings; 3 h/d, travelling 2

Author, year (reference)	Study sample	Assessment of sedentary behaviour	Limitations	Prevalence
	higher. Part of a continuous cross-sectional survey (Injuries and Physical Activity in the Netherlands). Sampling via random-digit dialling and computer-selected family member.	done on Sundays). Research undertaken evenly throughout the week. Questions also asked on occupation, sector, main activities, education, income, age, gender, education, number of hours at work, and family size.		h/d, full-time workers 3 h/d sitting and commuting. High-sit occupational groups include: legislators, senior managers, clerks, scientific and artistic professionals. Low-sit occupational groups include: agricultural workers, service workers, trade, industrial or transportation occupations, commercial workers. Regardless of sitting time during the day, evening sitting times differed only slightly between occupational groups.
Cross-sectional studies: recall method of sedentary behaviour undertaken, self report by participant				
(Shields & Tremblay, 2008)	42,612 Canadians aged 20−64 years from a nationally representative sample (CCHS); 19,811 men and 22,801 women.	Participants were asked the number of hours in a typical week over the past 3 months they spent watching TV (including videos), using a computer (including playing games and the internet), and reading.	Self-report data subject to social desirability and recall biases. Single-item measure for sedentary behaviours likely to yield only crude estimates of behaviours.	27% of men and 24% of women reported watching TV for 15 h+ per week; of which 16% of men and 15% of women reported 21 h+ per week. Frequent computer use (≥ 11 h/week) was reported by 18% of men and 14% of women. Frequent reading of more than 11 h/week was reported by 9% of men and 15% of women.
(Brown, Miller, & Miller, 2003)	529 Australian mothers participating in a child care intervention study; 185 adult Australian workers (men and women) participating in a workplace	Mothers filled in a self-completed questionnaire about total hours sitting during the last 7 days while travelling to and from places (car, train, bus) and as part of job, and for recreation. Workers were asked to estimate hours spent sitting on an average week day	Likely underestimate of prevalence of obesity and overweight. Non-random selection of participants. Different sitting time questions in the 2 studies. Self-report of sitting time.	Mothers spent on average 3.5 h/d sitting, made up of travel (0.6 h), work (1 h) and recreation (1.9 h). Workers spent on average 9.4 h/d sitting, made up of travel (1.2 h), work (4.9 h) and recreation (3.3 h).

Author, year (reference)	Study sample	Assessment of sedentary behaviour	Limitations	Prevalence
	pedometer study.	while at work, travelling, watching TV/using a computer, and for recreation.		
(Jakes, et al., 2003)	14,189 men (40%) and women; men aged 61 (9.0), women 59.9 (8.9) from Norfolk UK. Recruited from a population-based cohort of adults aged 45−74 from general practice lists.	Self-completed questionnaire on TV viewing.	Cross-sectional analysis of EPIC-Norfolk cohort study; removed participants who had heart attack (601), stroke (283), diabetes (442), before undertaking research (original participants n = 15,515).	On average, men watched 21.2 (10.1) h, and women, 21.9 (10.2) h of TV each week.
(Brown, Williams, Ford, Ball, & Dobson, 2005)	8071 Australian women aged 45−55 years from the Australian Longitudinal Study on Women's Health at 1996, 1998 and 2001.	2 questions about time spent sitting doing things like visiting friends, driving, reading, watching TV or working at a desk or computer were self-reported.	Sitting time questions only asked in 2001, so temporal relationship not present.	Average time spent sitting each day 17.3% < 3 h; 19.9% 3−4.5 h; 23.1% 4.5−6 h; 16.7% 6−8 h; 14.4% > 8 h; 8.7% missing data.
(Gordon-Larsen, Nelson, & Popkin, 2004)	Representative US sample of 13,030 participants (53% males, 47% females, 69% White, 15% Black, 12% Hispanic, 4% Asian); wave 1 ages ranging from 11−21 years, and wave 3 ages ranging from 18−26 years.	Self-report questionnaire of hours of TV watching, video watching, and computer / video game use over the past week. Data were summed to "screen time".	Self-report data. Only considered screen time as sedentary behaviour.	The proportion of early adults (18−26 years) in wave 3 who watched more than 14 hours of screen time per week were 52% White, 55% Black, 48% Hispanic, and 47% Asian.
(Brown, et al., 2004)	185 volunteers from a government workplace of approx. 400	Participants reported the number of hours they spent sitting at work, while travelling, while watching	Sample of working people in a single workplace only − not reflective of general population.	Average of 9.4 hours of sitting per day, with work sitting accounting for just over half of the average weekday

Author, year (reference)	Study sample	Assessment of sedentary behaviour	Limitations	Prevalence
	employees. Australian adults 18−75 years, average age 40.5 years.	TV, or using a computer on an average weekday. 30 participants undertook a repeat questionnaire 1 week later. A pedometer was worn during all waking hours for 7 consecutive days to record the number of steps taken.		sitting time (4.9 h/d). Time spent watching TV or using a computer at home (1.94 h/d) accounted for just over one-fifth of total sitting time on weekdays, and average time spent during travel was 1.2 h/d. Professional/managerial and administrative staff sat the longest at work and over the whole day (total 10.6 h/d and 10.3 h/d respectively). Technicians and blue-collar workers sat the least at work and over the whole day (total 7.8 h/d and 6.5 h/d respectively) ($p < 0.001$). There was a significant negative correlation between hours of sitting and number of steps taken, with professional/managerial and administrative staff taking the least number of steps per weekday, and technicians and blue-collar workers taking the most number of steps per weekday ($p < 0.0001$).
(Salmon, Owen, Crawford, Bauman, & Sallis, 2003)	Postal survey of 2872 eligible adults from the Australian electoral roll; 1332 responses.	1-week recall measure of time spent in 9 sedentary behaviours for the previous 7 days. Included computer use, hobbies, TV viewing, sitting and socialising, reading, sitting or lying down listening to music, talking on the phone, going for a recreational drive, and relaxing, thinking and reading. Validated questionnaire	Leisure time only, work not included. Low response rate led to selection bias. Self-reported data.	Respondents reported spending an average of 36.8 h during the previous week in 9 leisure-time sedentary activities. TV viewing was the most common behaviour (12.1 h men; 9.9 h women per week), with participants > 60 years watching significantly more TV (12.8 h/week) than any other age group.

Author, year (reference)	Study sample	Assessment of sedentary behaviour	Limitations	Prevalence
		using 3-day logs on 144 participants.		

Notes: Please see the notes for Appendix 3 for an explanation of the abbreviations used in this table.

Appendix 3: Table of studies investigating the association between sedentary behaviours, chronic disease and chronic disease risk

A full annotated bibliography of associations included in this review.

Author, year (reference)	Study sample	Assessment of sedentary behaviour	Assessment of disease/disease risk	Confounders adjusted for / limitations	Main outcomes
Cross-sectional studies					
(Bertrais, et al., 2005)	1902 males and 1932 females aged 50−69 years from France. Sub-sample of the SUVIMAX study.	Sedentary behaviour was assessed using a French self-administered version of the Modifiable Activity Questionnaire (MAQ). Participants were asked to report their average daily time spent at home watching TV, using a computer, and reading. Time spent watching TV and using a computer were summed.	Participants were considered to have the metabolic syndrome if they had at least 5 of the following characteristics (according to the NCEP criteria): 1. waist circumference > 102 cm (males), > 88 cm (females); 2. TAG > 1.69 mmol/L; 3. HDL-C < 1.29 mmol/L; 4. BP ≥ 130/85 mm Hg; 5. fasting glucose ≥ 6.1 mmol/L.	*Confounders adjusted for* Age, educational level, smoking status and physical activity. *Limitations* Only sedentary behaviour during leisure time was assessed. This was self-reported.	Time spent watching TV / using computer was positively associated with the likelihood of having the metabolic syndrome in females ($p < 0.0001$). Compared to < 2 h/d spent watching TV / using computer, the odds for having the metabolic syndrome were 1.74 for 2−3 h/d and 3.30 for ≥ 3 h/d. There was a tendency for this association in males ($p = 0.06$). No association was found between time spent reading and the risk of the metabolic syndrome in males or females.
(Bowman, 2006)	A nationally representative sample of 9157 male and females aged ≥ 20 years, from USA. *Data from US Dept of Agriculture's Continuing Survey of Food Intakes by Individuals*	Participants completed a questionnaire including 1 question on the number of hours they watched TV/videos per day.	BMI was calculated based on self-reported weight and height. 2 interviewer-administered, 24-hour recalls were collected on non-consecutive days, 3 to 10 days apart. Participants were asked whether a doctor had ever told them they had	*Confounders adjusted for* Age, sex, race and ethnicity, annual household income, region, urbanisation, exercise status. *Limitations* Only TV viewing was used to estimate sedentary behaviour. This was self-reported. Body weight and height	Both males and females who watched > 2 h/d of TV had a significantly higher BMI than those who watched TV < 1 h/d. Mean BMI (95% CI) for males who watched TV < 1 h/d and > 2 h/d were 25.4 (25.2−25.6) and 26.8 (26.6−27.0) respectively. Mean BMI (95% CI) for females who watched TV < 1 h/d and > 2 h/d were 24.7 (24.2−25.2) and 26.4 (26.0−26.7)

	1994−1996 (CSFII)		health conditions such as diabetes, hypertension, heart disease or high blood cholesterol.	were self-reported. CSFII (questionnaire) does not collect information on the time of day that TV is watched; it is not possible to provide direct evidence about what people ate when they watched TV. Small sample size in smaller racial/ethnic groups doesn't provide enough information for analysis.	respectively. A significantly higher percentage of overweight and obesity was observed for both males and females who watched > 2 h/d of TV compared to those who watched less that 1 h/d. Percent overweight (95% CI) among males who watched < 1 h/d TV and > 2 h/d was 50.8 (45.2−56.4) and 62.3 (59.8−64.8) respectively. There were significant differences in total energy intake between the different TV viewing categories. Adults who watched TV for less than 1 h/d had the lowest energy intake, while those who watched TV > 2 h/d had the highest energy, total fat, carbohydrate, sugars, and protein intakes. Adults who watched > 2 h/d of TV also consumed high amounts of energy-rich snack-type foods, grain-based foods such as pizza, regular soft drinks, and more energy at dinner and from snacks compared to adults who watched < 1 h/d. Non-significant for dietary fibre. Adults who watch < 1 h/d of TV had significantly lower daily energy intakes for daily total, supper and snacks than those watching > 2 h/d. Data non-significant for breakfast and lunch. A positive association was seen

					between viewing TV more than 2 h/d and having a health condition, including diabetes, hypertension, heart disease and high blood cholesterol.
(Brown, et al., 2003)	Study 1: 529 females (mothers) aged 18−64 years from Australia. Study 2: 74 male and 111 female (workers) aged 18−64 years from Brisbane, Australia.	Study 1: Mothers completed a survey in which they were asked to estimate their total time spent sitting during the last 7 days: (a) while travelling to and from places, (b) as part of your job, (c) for recreation (e.g. watching TV, dining out). Study 2: Workers completed a survey in which they were asked to estimate hours spent sitting on an average day: (a) at work, (b) travelling, (c) watching TV/using a computer (not work), (d) for recreation (e.g. socialising, movies, reading). Total sitting time was converted to h/d and categorised as low (< 4.7 h/d), moderate (4.7−< 7.4 h/d), or high (≥ 7.4 h/d).	BMI was calculated from self-reported heights and weights.	*Confounders adjusted for* Physical activity, work pattern. *Limitations* Body weight and height were self-reported. Non-random groups with limited generalisability. Sitting time questions differed between mothers and workers. Sedentary behaviour was self-reported. Non-random selection of participants. Control for limited number of confounders.	Results from study 1 and 2 were combined. Mean total sitting time increased significantly with BMI category (healthy weight: 4.8 ± 3.3h/d); overweight: 5.5 ± 3.5 h/d; obese 5.9 ± 3.9h/d; p < 0.01). There was a tendency for those in the highest sitting group (≥ 7.4 h) to be more at risk of being overweight than those in the low sitting group (OR: 1.61; 95% CI: 0.96−2.71, p < 0.074).
(Cameron, et al., 2003)	5049 males and 6198 females aged 25 years and over, from Australia. *Data from the AusDiab study. A*	Data on TV viewing was obtained by questionnaire. Time spent watching TV and/or videos was estimated for the previous week. Quintiles of TV watching were calculated separately	Height and weight were measured at a local survey centre and BMI calculated. Waist circumference was measured half-way between the lower	*Confounders adjusted for* Smoking status, physical activity, education, country of birth, income, and occupation. *Limitations*	For males BMI (OR: 1.86 [95% CI: 1.30−2.67]) and waist circumference (OR:1.97 [95% CI: 1.48−2.63]) was significantly higher in the highest quintile (> 1200 min/week) for TV viewing compared to the lowest quintile (<

	representative nationwide sample.	for males and females.	border of the ribs and the iliac crest on a horizontal plane.	Modest response rate of 55% and excluded rural and aboriginal populations. There were small differences between responders and non-responders. Only TV viewing was used to estimate sedentary behaviour. This was self-reported.	240 min/week). For females BMI (OR: 1.82 [95% CI:1.19−2.76]) and waist circumference (OR:2.27 [95% CI: 1.55−3.32]) was significantly higher in the highest quintile for TV viewing compared to the lowest quintile.
(Chang, et al., 2008)	1144 males and 1209 females aged ≥ 40 years from Taiwan.	Participants completed a self-administered questionnaire, including 1 question to determine time spent watching TV every week: "On average, how many hours a day (or a week) do you spend on watching TV?"	Participants were defined as having the metabolic syndrome if they had 3 or more of the following 5 criteria: waist circumference > 90 cm for males and > 80 cm for females; blood triglycerides ≥ 1.695 mmol/L; HDL-C < 1.036 mmol/L in males and < 1.295 mmol/L in females, BP ≥ 130/85 mm Hg; fasting glucose ≥ 6.1 mmol/L.	*Confounders adjusted for* Age, level of education, household income, occupational activity status and smoking. *Limitations* TV viewing time was the only measure of sedentary behaviour. This was self-reported.	Compared to participants who viewed TV < 14 h/week, those who viewed TV > 20 h/week, males and females respectively, had a 1.50-fold (95% CI: 1.10−2.03) and 1.93-fold (95% CI: 1.37−2.71) chance of having the metabolic syndrome. No significant relationship was found when comparing the 14−20 h/week TV viewing group with the < 14 h/week TV viewing group.
(Ching, et al., 1996) (*also see prospective data from this study below)*	22,076 males aged 40−75 years, from the Health Professionals Follow-up Study in the US. *Data from The Health Professionals Follow-up Study*	Participants completed a self-administered, mailed questionnaire. Time reported watching TV/videos each week was the indicator of sedentary behaviour. Participants were placed within 1 of 6 time categories (0−1 h; 2−5 h; 6−10 h; 11−20 h; 21−40 h, ≥ 41 h).	Self-reported body weight and height were used to calculate BMI.	*Confounders adjusted for* Age, smoking status, quintile of non-sedentary activity level. *Limitations* Only TV viewing was used to estimate sedentary behaviour. This was self-reported. Body weight and height were self-reported.	Increasing time spent watching TV/videos was associated with an increased prevalence and odds ratio (OR) of being overweight. The increase was evident with only 2−5 h/week of TV/video viewing (OR -1.42; 95% CI: 1.14−1.77) compared to 0−1 h/week. For males watching TV/videos ≥ 41 h/week were 3.88 (95% CI: 2.55−5.92) times more likely to be overweight than those

				The findings are limited to middle- to older-aged males of relatively high SES.	watching < 1 h/week. The trend for increased risk of being overweight as viewing time increased was significant (p = 0.002). The relationship between TV/video viewing and the odds of being overweight was independent of physical activity levels.
(Conus, et al., 2004)	12 metabolically obese but normal-weight women (MONW) and 84 non-MONW based on insulin sensitivity. Participants were recruited from Canada.	Participants reported hours of watching TV/video per week in a lifestyle questionnaire.	Insulin sensitivity was measured by HOMA = (fasting insulin [μU/ml] x fasting glucose [mmol/L])/22.5	*Confounders adjusted for* Percentage body fat. *Limitations* TV/video viewing was the only measure of sedentary behaviour. This was self-reported. Small study numbers: only 12 MONW.	Hours of TV/video viewing per week were significantly higher in the MONW compared to the non-MONW (9.3 ± 3.8 h vs 6.2 ± 4.5 h; p = 0.029). HOMA was positively correlated with hours of viewing TV/videos (r = 0.309, p = 0.003). Stepwise regression indicated that TV viewing was not an independent predictor of insulin sensitivity as assessed by HOMA.
(Crawford, Jeffery, & French, 1999) *(see prospective data below)*	176 males, 428 high-income females and 277 low-income females aged 20−45 years, from Australia.	Participants were asked to report how many hours of TV they watched on an average day. Average daily TV viewing for each participant during the study period was calculated.	BMI was calculated from measured weight and height.	*Confounders adjusted for* Baseline BMI, treatment group, age, education, baseline smoking, energy intake, percentage energy from fat. *Limitations* Only TV viewing was used as a measure of sedentary behaviour. This was self-reported. Low-income men were not part of the cohort.	Baseline cross-sectional data showed a positive relationship between TV viewing and BMI among females, but not males. The relationship was strongest for low-income females Regression coefficient: 0.52 (95% CI: 0.15−0.89).
(Dunstan, et al., 2004) *(same sample as*	8299 males and females aged ≥ 25 years, from	TV viewing time was assessed using an interviewer-administered questionnaire. Participants	An oral glucose tolerance test (OGTT) was performed.	*Confounders adjusted for* Age, education level, cigarette smoking, parental history of diabetes, dietary	Compared with those who watched TV < 14 h/week, watching TV > 14 h/week was associated with an increased risk

Dunstan 2007)	Australia.	reported the total time spent watching TV or videos in the previous week. The average hours of TV viewing per week was used to create 3 categories (0−7, 7.01−14, > 14 h/week).		covariates. *Limitations* TV viewing was the only measure of sedentary behaviour.	of having new type 2 diabetes in females (OR = 2.2; 95% CI: 1.32−3.61) and males (OR = 2.4; 95% CI: 1.41−4.12). After controlling for all covariates except for waist,* higher levels of TV viewing were associated with an increased risk of having abnormal glucose metabolism in females (p = 0.008) but not in males. Inclusion of waist circumference into the model led to attenuation of the association (p = 0.10). After controlling for all covariates except for waist,* for each 1 h/d increase in time spent watching TV there was an 18% (95% CI: 9−29, p = 0.001) and a 7% (95% CI: 4−19, p = 0.21) increase in the risk of abnormal glucose metabolism in females and males, respectively. Compared with those who watched TV < 14 h/week, watching TV > 14 h/week was associated with an increased risk of impaired glucose tolerance in females (OR = 1.34; 95% CI: 0.99−1.81). * It is argued that adjustment for waist circumference in regression models may constitute statistical overcorrection and lead to an underestimation of the true beneficial effect.
(Dunstan, et al., 2005)	2831 males and 3331 females aged > 35 years from Australia.	Participants reported total time spent watching TV or videos in the previous week. Total time spent watching TV was used to create 3	Participants were defined as having the metabolic syndrome based on the 1999 WHO criteria.	*Confounders adjusted for* Age, education, family history of diabetes, cigarette smoking, dietary covariates (total energy, total fat, total	Mean TV viewing time was higher for those with the metabolic syndrome compared to those without (p = 0.01 for males and p = 0.0001 for females). The

	The sample is from the AusDiab study.	categories: 0−7 h/week, 7.01−14 h/week and > 14 h/week.	Participants were defined as having the metabolic syndrome if they had insulin resistance, impaired glucose tolerance, or diabetes, and at least 2 of the following: 1. obese, 2. dyslipidaemia (TAG ≥ 1.7 mmol/L or HDL-C < 0.9 mmol/L for men or < 1.0 mmol/L for women); 3. hypertension (BP ≥ 140/90 mm Hg or on antihypertensive medication); 4. microalbuminuria.	saturated fat, total carbohydrate, total sugars, fibre, alcohol) and total physical activity. *Limitations* Only TV viewing was measured to represent sedentary behaviour. This was self-reported.	risk of having the metabolic syndrome increased as TV viewing increased across tertiles of TV viewing (relative to ≤ 7 h/d, 7−14 h/d OR = 1.17, 95% CI: 0.78−1.76; > 14 h/d OR = 2.07, 95% CI: 1.49−2.88; p-value for trend = 0.0001). Compared to viewing ≤ 14 h/d, > 14 h/d was positively associated with insulin resistance (OR = 1.63, 95% CI: 1.29−2.06 for females, p = 0.0001), obesity (OR = 1.57, 95% CI: 1.22−2.01, p = 0.001 for males and OR = 1.68, 95% CI: 1.20−2.34, p = 0.003 for females), dyslipidaemia (OR = 1.63, 95% CI: 1.23−2.15 for females).
(Dunstan, et al., 2007) *(same sample as Dunstan 2004)*	3781 males and 4576 females aged 36−91 years from Australia.	TV viewing time was assessed using an interviewer-administered questionnaire. Participants reported the total time spent watching TV or videos in the previous week.	Two oral glucose tolerance tests (OGGT) were performed. HOMA was used to assess insulin resistance.	*Confounders adjusted for* Age, height, waist, total energy intake, total fat intake, total saturated fat intake, total carbohydrate intake, total sugar intake, total fibre intake, alcohol intake, total physical activity, current smoking status, parental history of diabetes, and university/further education. *Limitations* TV viewing was the only measure of sedentary behaviour. This was self-reported.	After adjustment for age, there was a significant positive association between TV viewing and fasting plasma glucose (FPG) concentration in females (p = 0.002), and a tendency for this association in males (p = 0.06). A positive association between TV viewing and 2-h plasma glucose (PG) concentrations were observed in both females (p = 0.001) and males (p = 0.03). Each 1 h/d increase in TV time increased FPG by 0.04 (95% CI: 0.03−0.06, p = 0.001) in females and 0.02 mmol/L (95% CI: 0.001−0,04, p = 0.04) in males. The increase in 2-h plasma glucose concentration was 0.16 mmol/L (95% CI: 0.08−0.25, p =

					0.001) in females and 0.11 mol/L (95% CI: -0.001−0.23, p = 0.06) in males. Using multiple regression analysis, there was a significant positive association with 2-h PG concentrations (p = 0.02). The mean was 0.5 mmol/L higher in those watching > 3 h of TV/d compared with those watching < 1 h/d. This association approached significance in males (p = 0.06). No association was seen with TV viewing and FPG in males or females. TV viewing was positively associated with fasting insulin (p = 0.0001) and HOMA-beta cell function (p = 0.04) and inversely associated with HOMA-insulin sensitivity (p = 0.0001) in females only.
(Ekelund, et al., 2007)	258 males and females aged 30−50 years, with a family history of diabetes, from the UK. Participants in ProActive Study, a randomised controlled trial carried out on people at risk of type 2 diabetes aged 30−50 years.	An MTI ActiGraph accelerometer was used to measure sedentary time during waking hours for 4 consecutive days. A cut-off of < 100 counts/min was chosen to define sedentary time.	Body weight and height were measured. Waist circumference was measured in duplicate. Bioimpedance was used to measure body fat. BP was measured in triplicate. Fasting blood samples were taken to measure glucose, TAG, HDL-C and insulin. A standardised variable for clustered metabolic risk was calculated.	*Confounders adjusted for* Age, sex and waist circumference. *Limitations* Removed very active and very sedentary individuals from study. Limited to sedentary, overweight middle-aged Caucasian individuals with family history of type 2 diabetes.	Sedentary time was only positively associated with fasting insulin levels (p = 0.049).
(Fitzgerald, Kriska, Pereira, & de Courten,	2452 male and female Pima Indians aged 21−59	Questionnaires administered by trained interviewers assessed TV viewing by one	Body weight and height were assessed and BMI calculated.	*Confounders adjusted for* Age, diabetes, sex.	TV viewing was significantly positively associated with BMI in males (p = 0.009), but not in

1997)	years.	question: "In general, about how many hours per day did you spend watching TV?"	Waist and thigh circumference were measured.	*Limitations* Only TV viewing was used to estimate sedentary behaviour. This was self-reported. Results may not be able to be extrapolated to other populations.	females.
(Ford, et al., 2005)	812 males and 814 females aged ≥ 20 years, from USA. *Data from the National Health and Nutrition Examination Survey 1999/2000.*	Time spent watching TV or videos, or using a computer, was determined from an interviewer-assisted questionnaire. Participants were asked: "Over the past 30 days, on a typical day how much time altogether did you spend sitting, watching TV or videos or using a computer outside of work?" Answer choices were < 1h, 1 h, 2 h, 3 h, 4 h, ≥ 5 h per day.	Participants were defined as having the metabolic syndrome if they had 3 or more of the following 5 criteria (based on the NCEP criteria): waist circumference > 102 cm for males and > 88 cm for females; blood TAG ≥ 1.695 mmol/L; HDL-C < 1.036 mmol/L in males and < 1.295 mmol/L in females, BP ≥ 130/85 mm Hg; fasting glucose ≥ 6.1 mmol/L.	*Confounders adjusted for* Age, sex, race, ethnicity, educational status, smoking status, alcohol use, and physical activity. *Limitations* Only measured leisure-time sedentary behaviour, not at work. This was self-reported.	The age-adjusted prevalence of the metabolic syndrome increased as the amount of time watching TV, videos or using a computer increased. There was a tendency for the odds associated with having the metabolic syndrome to increase steadily as the number of hours watching TV, videos or using a computer increased. For males, < 1 h OR:1; 1 h OR:1.41 (95% CI: 0.79−2.52); 2 h OR:1.38 (95% CI: 0.85−2.23); 3 h OR:1.74 (95% CI: 0.94−3.23); ≥ 4 h OR: 2.07 (95% CI:1.23−3.46); (p = 0.067). For females < 1 h OR:1; 1 h OR:1.64 (95% CI: 0.70−3.86); 2 h OR:1.59 (95% CI: 0.81−3.13); 3 h OR:1.50 (95% CI: 0.66−3.41); ≥ 4 h OR: 2.67 (95% CI:1.19−6.41); (p = 0.120).
(Fotheringham, Wonnacott, & Owen, 2000)	216 male and 481 female students aged 18−30 years from Australia, attending a city university.	Participants completed a self-administered survey from which time spent using a computer for study or course work, paid employment, non-study non-recreational purposes, recreational use of the	BMI was calculated based on self-reported weight and height. Participants completed a self-administered survey where they recalled physical activity over 2 weeks.	*Confounders adjusted for* Age, gender, BMI, and activity levels. *Limitations* This was a student group and findings may not be able to be extrapolated to other	BMI was not associated with level of computer use. Participants reporting computer use for 3−8 h/week were 1.63 times more likely to be inactive than those reporting computer use for < 3 h/week (OR 1.63, 95% CI 1.00−2.65).

		Internet and playing computer games, was summed. Tertiles of time spent using computers were calculated (low: < 3 h/week; moderate: 3−8 h/week; high: > 8 h/week).		populations. Only computer use was assessed as a measure of sedentary behaviour. This was self-reported. Body weight and height were self-reported.	Participants reporting computer use for > 8 h/week were 2.23 times more likely to be inactive than those reporting computer use for < 3 h/week (OR = 2.23, 95% CI 1.39−3.59). Inactive participants reported computer use to be a common barrier to physical activity more often than active participants ($p < 0.003$).
(Gao, Nelson, & Tucker, 2007)	350 Puerto Rican and 105 Dominican elders, aged ≥ 60 years living in Massachusetts, USA. Randomly sampled from census blocks.	Information on the number of hours spent watching TV in the past week was collected by questionnaire.	Participants were defined as having the metabolic syndrome if they had 3 or more of the following 5 criteria: waist circumference > 102 cm for males and > 88 cm for females; blood TAG ≥ 1.7 mmol/L; HDL-C < 1.04 mmol/L in males and < 1.30 mmol/L in females, BP ≥ 130/85 mm Hg or currently using anti-hypertensive medication; fasting glucose ≥ 5.55 mmol/L or current use of medications for diabetes.	*Confounders adjusted for* Age, sex, ethnicity, education, BMI, household arrangement, smoking, current alcohol use, total energy intake, saturated fat %TE, polyunsaturated fat %TE, trans fat %TE, fruit and vegetable intake, physical activity score, and activities of daily living (ADL) score. *Limitations* TV viewing time was the only measure of sedentary behaviour. This was self-reported. Findings limited to older, Hispanic populations. Door-to-door contact of elderly people may have biased those who stay at home rather than those who are active and away from home.	More frequent TV viewing was associated with a higher prevalence of the metabolic syndrome (p for trend = 0.002) and the number of individual metabolic abnormalities (p for trend = 0.006). Only those in the highest quartile of TV viewing (5.6−18 h/d) had a significantly high odds ratio for the metabolic syndrome: OR 2.2, 95% CI: 1.1−4.2; $p < 0.05$) and number of abnormalities ($p < 0.05$) compared to those in the lowest quartile (0−1.5 h/week). Each additional hour per day of TV viewing was associated with a 16% greater likelihood of having the metabolic syndrome (OR 1.19; 95% CI: 1.1−1.3, p for trend = 0.002). Greater TV viewing was associated with a greater risk of low HDL-C (p for trend = 0.01), high TC to HDL-C ratio (p for trend = 0.04) and a high waist-to-hip ratio (p for trend = 0.0006). Non-significant for abdominal obesity, hypertriglyceridaemia, high fasting glucose and high

					BMI.
(Giles-Corti, Macintyre, Clarkson, Pikora, & Donovan, 2003)	523 males and 1069 female sedentary workers and homemakers, aged 18−59 years from Perth, Australia.	Trained interviewers were used. Participants reported hours per week of TV viewing. This was coded as hours of viewing per day.	Height and weight were self-reported and BMIs calculated.	*Confounders adjusted for* Age, sex, educational levels, occupation, area of residence, smoking and physical activity. *Limitations* Only TV viewing was used to estimate sedentary behaviour. This was self-reported. A relatively modest response rate of 53%. Body weight and height were self-reported.	The odds of being overweight were nearly twice those in participants who viewed ≥ 3 h/d of TV compared to those watching < 3 h/d (OR = 1.92, 95% CI: 1.33−2.79). The odds of being obese were also positively associated with TV viewing. The OR for those viewing ≥ 3 h/d compared to those watching < 3 h/d was 1.85 (95% CI: 1.13−3.04).
(Gortmaker, et al. 1990)	778 male and female faculty staff and students at Harvard School of Public Health, USA.	Participants completed self-administered questionnaires in 1986 and 1987, where they reported their weekly hours of TV viewing.	Height and weight were self-reported and BMIs were calculated.	*Confounders adjusted for* Age, diet, physical activity and time spent sleeping. *Limitations* Only TV viewing was used to estimate sedentary behaviour. This was self-reported. Body weight and height were self-reported. All participants were members of Harvard School of Public Health, therefore results may not be generalisable to other populations.	Among those reporting ≤ 1h /d TV viewing, the prevalence of obesity was 4.5%; among those reporting ≥ 3 h/d the prevalence was 19.2%, p < 0.001). TV viewing was independently, positively associated with obesity (p < 0.0001).
(Healy, et al., 2007)	67 females and 106 males with a mean (s.d.) age of 53.3 (11.9) years, from Australia.	A uniaxial accelerometer was used to measure sedentary time during waking hours for 7 consecutive days. A cut-off of < 100 counts/min was	Participants underwent an oral glucose tolerance test. Outcome variables included fasting plasma glucose and 2-hour plasma	*Confounders adjusted for* Age, sex, time accelerometer worn, height, waist circumference, accelerometer unit, family history of diabetes, alcohol	Higher sedentary time was associated with significantly higher 2-hour plasma glucose (p = 0.019). Sedentary time was only significantly positively associated with fasting plasma glucose levels

		chosen to define sedentary time.	glucose levels.	intake, education, income, smoking status, moderate to vigorous physical activity.	in the age-adjusted model (p = 0.046). The association became non-significant following adjustment for further potential confounders.
(Healy, Wijndaele, et al., 2008)a *(same study sample as Healy* Dunstan, Salmon, Cerin, et al., *2008c)*	67 males and 102 females aged 30−87 years from Australia.	A uniaxial accelerometer was used to measure sedentary time during waking hours for 7 consecutive days. A cut-off of < 100 counts/min was chosen to define sedentary time.	Waist circumference, TAG, HDL-C, BP, and fasting plasma glucose were measured to assess metabolic risk. A clustered metabolic risk score was calculated based on these risk variables.	*Confounders adjusted for* Age, sex, employment status, alcohol intake, income, education, smoking status, diet quality, family history of diabetes, cholesterol-lowering medication, physical activity, and hypertensive medication. *Limitations* Relatively small sample size.	Sedentary behaviour was significantly positively associated with waist circumference, TAG, and clustered metabolic risk score, but not with HDL cholesterol, blood pressure, or fasting plasma glucose. On average, each 10% increase in sedentary time was associated with a 3.1 cm (95% CI: 1.2−5.1) larger waist circumference. Independent of time spent in moderate to vigorous physical activity, there were significant associations with sedentary behaviour with waist circumference and clustered metabolic risk. Sedentary time and time spent in light activities were strongly correlated, but sedentary or time spent in light activities were not strongly correlated with time spent in moderate to vigorous activities.
(Healy, Dunstan, Salmon, Shaw, et al., 2008)b	2031 men and 2033 women aged ≥ 25 years from Australia. All participants reported that they performed at least 2.5 h/week of moderate to vigorous physical	Participants completed questionnaires reporting total time spent watching TV/videos in the previous week.	Participants underwent an oral glucose tolerance test. Fasting and 2-hour plasma glucose levels, fasting TAG, and HDL-C were measured. Duplicate waist circumference and triplicate resting BP measures were	*Confounders adjusted for* Age, education, income, smoking, diet quality, alcohol intake, parental history of diabetes, total physical activity time, and menopausal status and current use of postmenopausal hormones for women.	For females, each quartile increase in TV-viewing time was associated with a significant mean increase in waist circumference (p-value for trend < 0.001), fasting glucose (p value for trend = 0.011), 2-hour plasma glucose (p-value for trend < 0.001), triglycerides (p-value for trend < 0.001), systolic BP (p-value for

	activity.		taken.	*Limitations* Only TV viewing was used to assess sedentary behaviour. This was self-reported.	trend < 0.039), and a significant decrease in HDL-C (p-value for trend < 0.001). Women who were sufficiently active, and who watched > 2.57 h TV/d were significantly more likely to have higher waist circumference (4.22, 95% CI: 2.81 −5.63), systolic BP (2.53, 95% CI: 0.77−4.30), fasting plasma glucose (0.007, 95% CI: 0.02−0.05), 2-h plasma glucose (0.035, 95% CI: 0.02−0.05), triglycerides (0.06, 95% CI: 0.04−0.09) and HDL cholesterol (-0.12, 95% CI: -0.16 to -0.07) than women who were sufficiently active and watched < 0.93 h TV/d. Non-significant for diastolic BP. For males, each quartile increase in TV-viewing time was associated with a significant mean increase in waist circumference (p-value for trend < 0.001), systolic BP (p-value for trend = 0.023), and 2-h plasma glucose (p-value for trend < 0.001). For all metabolic variables, the associations to TV viewing time were stronger in females than in males. Men who were sufficiently active, and who watched > 2.57 h TV/d were significantly more likely to have higher waist circumference (2.62, 95% CI: 1.35−3.88) and 2-h plasma glucose (0.035, 95% CI:

					0.02−0.05) than men who were sufficiently active and watched < 0.93 h TV/d. Non-significant for systolic and diastolic BP, fasting plasma glucose, TAG and HDL-C. When further adjusted for waist circumference, 2-h plasma glucose for men, and 2-h plasma glucose, triglycerides and HDL cholesterol for women, remained significantly associated.
(Healy, Dunstan, Salmon, Cerin, et al., 2008)c *(same study sample as Healy* & Wijndaele, et al *2008)*	168 males and females aged 30−87 years from Australia.	Breaks in sedentary time were the primary measure of interest. A uniaxial accelerometer was used to measure sedentary time during waking hours for 7 consecutive days. A cut-off of < 100 counts/min was chosen to define sedentary time. A break in sedentary time was considered as an interruption in sedentary time (minimum 1 min) in which the accelerometer count rose to or above 100 counts/min.	Participants underwent an oral glucose tolerance. Fasting and 2-h plasma glucose levels, fasting TAG and HDL-C were measured. Duplicate waist circumference and triplicate resting BP measures were taken.	*Confounders adjusted for* Age, sex, employment, alcohol intake, income, education, smoking, family history of diabetes, diet quality, moderate to vigorous exercise time, mean intensity of breaks, total sedentary time. *Limitations* This study measured breaks in sedentary time rather than sedentary time *per se.*	Overall, fewer breaks in sedentary time were positively associated with waist circumference (p = 0.027), BMI (p = 0.026), triglycerides (p = 0.029) and 2-h plasma glucose (p = 0.025). There were no significant associations between sedentary time and HDL-cholesterol, blood pressure or fasting plasma glucose levels. Compared to those in the lowest quartile of breaks in sedentary time, those in the highest quartile had, on average, a 5.95 cm lower waist (p = 0.025), and a 0.88 mmol/L lower 2-h plasma glucose (p = 0.019).
(Jakes, et al., 2003)	14,189 men (40%) and women; men aged 61 years, women 59.9; years from Norfolk UK. Recruited from a population-based cohort of adults	Self-completed questionnaire on television viewing; EPIC Physical Activity Questionnaire (EPAQ2).	Trained nurses took measurements of; height, weight, waist, hip, blood pressure, body fat (using Tanita Body Fat Monitor). Blood samples were taken for cholesterol, HDL, cholesterol and	*Confounders adjusted for* Controlled for age, alcohol intake, smoking habit, use of anti-hypertensive therapy. *Limitations* Cross-sectional analysis of the EPIC-Norfolk cohort study; removed participants	All markers of obesity (BMI, waist, hip, waist:hip, % body fat) *significantly* increased with the amount of TV viewing time for both men and women (p < 0.001 for all). All markers of cardiovascular risk (diastolic BP, systolic BP,

	aged 45−74 from general practice lists.		triglyceride.	who had heart attack (601), stroke (283), diabetes (442) before undertaking research (original participants n = 15,515).	cholesterol, LDL cholesterol, HDL cholesterol, triglyceride) were significantly higher for those watching > 4 h/d than those watching < 2 h/d for both men and women (p < 0.001 for all except for HBA1C, which was non-significant).
(Jeffery & French, 1998) *(also see prospective data from this study below)*	198 males and 529 females with high income, and 332 low-income females aged 20−45 years, from USA.	TV viewing was assessed by 1 item in a questionnaire: "On an average day, how many hours of TV do you watch?"	Body weight was measured in light clothing and height was recorded. BMI was calculated from these height and weight measurements. Physical activity was measured by a questionnaire. The frequency with which each of 12 exercise activities was performed for ≥ 20 min over the previous year was assessed. A total exercise score was calculated as the sum across all 12 items, of the reported frequency per week for each activity multiplied by its estimated intensity in metabolic equivalents. Total energy intake per day and percentage of energy from fat were estimated from a 60-item Block FFQ.	*Confounders adjusted for* Age, education, baseline smoking, BMI, treatment group. *Limitations* Only TV viewing was used to estimate sedentary behaviour. This was self-reported. Populations were specifically high-income men and women and low-income women, therefore results may not be able to be extrapolated to low-income males and middle-income groups. Generalisability is also limited because the sample was composed of volunteers for a weight-gain-prevention trial.	Average TV viewing per day was 1.9 h, 1.8 h and 3.1 h for males, high-income females and low-income females, respectively. In both high- and low-income females, TV viewing was positively associated with BMI. A 1-h/d increase in TV viewing was associated with a 0.30 (95% CI: 0.02−0.58) higher BMI unit in high-income females; and a 0.59 (95 % CI: 0.27−0.91) increase in low-income females. There was no association among males. Physical exercise was not significantly associated with TV viewing in males, high- or low-income females. TV viewing was not significantly associated with energy or fat intake in males. TV viewing was significantly positively associated with daily energy intake and percentage of calories from fat in both high- and low-income females. Each 1-h increase in TV viewing was associated with a 50 kcal (220 KJ) (95% CI: 20−80) per day increase in energy for high-income women and a 136 kcal/day (570 KJ) (95% CI: 68−204) increase for low-

					income women.
(Kronenberg, et al., 2000)	816 Caucasian males aged (mean [s.d.] 48 [14]) years and 962 Caucasian females aged (mean [s.d.] 49 [13]) years, from USA.	Trained interviewers administered questionnaires. Participants were asked for the number of hours spent watching TV for both weekdays and weekend days. The average hours of watching TV per day was calculated.	Trained personnel measured BP in triplicate, body weight and height, waist and hip circumference, subscapular and triceps skinfolds. A blood test was taken for measurement of total cholesterol, HDL-C, LDL-C, TAG, and glucose. Trained technicians scanned the carotid arteries at three sites bilaterally in 897 females and 761 males.	*Confounders adjusted for* Leisure-time physical activity, activity level at work, age, centre (multicentre study), drinking and smoking habits, degree of education and income, post-menopausal status and oestrogen use in females. *Limitations* Only TV viewing was used to estimate sedentary behaviour. This was self-reported.	TV viewing was significantly positively associated with BMI (p = 0.001, females and males), waist circumference (p = 0.001, females and males), waist−hip ratio (p = 0.003 females, p = 0.002 males), subscapular (p = 0.001 females, p = 0.0092 males) and triceps (p = 0.0004 females only). Skinfold thickness, systolic BP (p = 0.002 for females only), diastolic BP (p = 0.073 females only), HDL-C (p = 0.018 males only), TAG (p = 0.036 females, p = 0.0009 males), and glucose (p = 0.0026 females, p = 0.0001 males).TV viewing was not correlated with carotid intima-media thickness.
(Leite & Nicolosi, 2006)	1415 subjects (49.8% men) average ages of 56.8 men and 56.5 women. 44.4% of men were employed, 55.6% were retired; 24.2% of women were employed, 40.6% of women were retired, 35.2% were "housewives". Random sample of all individuals aged 40−74 years drawn from residents list	Interviewer-administered − time spent watching TV was reported.	Interview regarding anthropometric (height, weight, waist circumference, hip circumference, skin folds at biceps, supra-iliac crest, triceps, subscapular).	*Confounders adjusted for* All results adjusted for age, height and total energy intake; body muscle mass. *Limitations* Possible self-selection bias due to recruitment technique (letter sent to subjects to invite their participation). Cross-sectional study. No description of how TV watching question was phrased.	BMI was significantly higher for those women who spent more time watching TV (2−3 h/d 21.7%, > 4 h/d = 26.5%) than those watching < 2 h/d (p < 0.01). The data were not significant for men. Waist circumference was significantly higher in men watching TV for longer (2−3 h/d = 15.1%, > 4 h/d = 18.6%) than women watching < 2 h/d (p < 0.01); and hip circumferences were significantly lower in men watching TV the longest (> 4 hours/day = -18.1%) than those watching < 2 h/d (p = 0.05).

	of the town of Bollate (Milan, Italy).				
(Li, Lin, Lee, & Tseng, 2007)	358 males and females aged 20−60 years from Linkou, Taiwan.	Participants were interviewed and asked to report their average daily time spent sitting at home watching TV/videos/DVDs. Responses were grouped into 3 categories: 0−5, 6−20, ≥ 21 h/week.	The NCEP Expert Panel on Detection, Evaluation and Treatment of High Blood Cholesterol in Adults was used to define the metabolic syndrome, which was defined as having 3 of the following: obesity: waist circumference > 90 cm for males and > 80 cm for females (Asian criteria); hypertriglyceridaemia: ≥ 1.695 mmol/L; low HDL-C: ≤ 1.036 mmol/L for males and ≤ 1.295 mmol/L in females; high BP: ≥ 130/95; and high fasting blood glucose ≥ 6.1 mmol/L.	*Confounders adjusted for* Gender, age, BMI and physical activity. *Limitations* TV viewing time was the only measure of sedentary behaviour. This was self-reported. A convenient sample, but may not be generalisable.	The odds ratio of having the metabolic syndrome in participants who watched ≥ 21 h/week compared with participants who watched < 5 h/week was 3.69 (95% CI: 1.05−12.95, p = 0.030). Controlling for physical activity reduced the OR to 2.00 (95% CI: 0.83−10.84, p = 0.095). Watching 6−20 h/week was not associated with an increased risk. Participants watching ≥ 21 h/week had significantly greater odds of high TAG levels OR = 2.51 (95% CI: 1.04−6.07, p = 0.041) and high fasting glucose concentrations OR = 11.66 (95% CI: 1.39−97.54, p = 0.023).
(Liebman, et al., 2003)	928 males and 889 females aged 18−99 years, from 6 rural communities in Wyoming, USA.	Participants completed a survey including questions on time spent watching TV, leisure time spent on the computer or playing video games.	Height and weight were self-reported and BMI calculated.	*Confounders adjusted for* Age, gender, race, level of education, dietary intake/eating behaviour and physical activity. *Limitations* Body weight and height were self-reported. A relatively modest response rate of 51%. Sedentary behaviour was	Viewing TV was positively correlated with overweight (p = 0.005) and obesity (p = 0.0017). No correlation was found between overweight/obesity and playing computer/video games. Watching TV was a more powerful predictor of obesity in participants aged < 50 years compared to those aged ≥ 50 years. Compared to those watching TV < 2 h/d, those

				self-reported.	watching ≥ 4 h/d were significantly more likely to be obese in each age/gender category.
(Martinez-Gonzalez, Martinez, Hu, Gibney, & Kearney, 1999)	15,239 males and females aged over 15 years, from 15 European Union countries. The samples were nationally representative of the EU countries.	Questionnaires were interviewer-administered in the participants' home. Sedentary behaviour was assessed through the number of hours spent sitting down during leisure time per week. Participants were asked: "In your leisure time, how many hours on average do you spend sitting down – watching TV/videos, playing computer games, reading or listening to music, etc?" Options were given for a typical weekday and a typical weekend day.	BMI was calculated based on self-reported weight and height.	*Confounders adjusted for* Age, educational level, social class, marital status, smoking habits, recent weight loss, and country. *Limitations* Body weight and height were self-reported. Only sitting time during leisure time was measured. This was self-reported.	The prevalence of overweight and obesity was higher for males and females among those who spent a longer time sitting (prevalence of obesity was 7.6% for those watching < 15 h/week compared to 13.3% for those watching > 35 h/week for males and 9.2 vs 12.4 for females). Sitting time was significantly positively associated with BMI in males (p = 0.006) and females (p < 0.001). The OR for obesity increased across quintiles of sitting time. The OR for sitting > 35 h/week was 1.61 (95% CI:1.33−1.95) compared to less than 15 h/week.
(Mummery, et al., 2005)	1579 Australians, full-time employees aged 18+ from a telephone sample of households in 2 Queensland communities; 875 males and 704 females.	Participants were asked to recall the number of minutes sitting while at work during a normal working day.	Body weight; height and weight by self report, BMI ≥ 25.	*Confounders adjusted for* Gender, age, occupational category, leisure-time activity. *Limitations* Response rate of 44%. Self-report data subject to social desirability and recall biases. Single-item measure for sedentary behaviours likely to yield only crude estimates of behaviours. Questionable variation in female occupational sitting time.	Men who sat for > 6 h were nearly twice as likely to have a BMI ≥ 25 (OR = 1.92) than those who sat for < 45 min/d. No relationship between occupational sitting time and BMI ≥ 25 for women.
(Oppert, et al.,	405 adults: 192	In a self-completed	Measured height and	*Confounders adjusted for*	In women, screen viewing was

2006)	women and 213 men; average age 43 years. Participants in the Fleurbaix-Laventie Ville-Sante study, 2 cities in Northern France.	questionnaire, subjects were asked to report their average daily time spent at home watching TV/video or playing video games, using a computer (all summed to "screen viewing"), and reading for leisure.	weight. Bioimpedance measured.	Gender, education, age. *Limitations* Assesses sedentary behaviours at both leisure time and work using a validated questionnaire, but self-report so issues of misclassification and over-reporting. Semi-rural cities may limit generalisability Cross-sectional design. Reading in high educational level men may be a marker for other health-promoting behaviours.	positively associated with percent body fat in women ($p = 0.006$) and low educational level women ($p = 0.01$).[6] Reading was negatively associated with percent body fat in high educational level men ($p = 0.01$), but not for low educational level men or women, or high educational level women.
(Pietroiusti, et al., 2007)	Call centre workers of an Italian telecommuni-cations company were recruited. 1547 workers using visual display units for at least 25 h/week, mean age 29.7 years; 892 workers using computers less than 20 h/week, mean age 30.2 years.	Cases: workers who used visual display units ≥ 25 h/week. Controls: workers who used computers < 20 h/week.	Metabolic syndrome was defined according to the updated NCEP. The metabolic syndrome was deemed present if 3 or more of the following conditions were present: waist circumference > 102 cm for males and > 88 cm for females; blood TAG ≥ 1.7 mmol/L; HDL-C < 1.04 mmol/L in males and < 1.30 mmol/L in females; BP ≥ 130/85 mm Hg or currently	*Confounders adjusted for* Smoking, leisure-time physical activity, job stress. The exposed and controls were matched for age, gender, work schedule, education, income, work seniority, and family history. *Limitations* Only work-time sedentary behaviour was measured.	A 30% increase in the prevalence of the metabolic syndrome was observed among visual display unit (VDU) users compared to the controls. The OR (95% CI) for having the metabolic syndrome among VDU users versus controls was 1.6 (CI: 1.0−2.7), $p < 0.05$. The prevalence of high waist circumference ($p = 0.002$), high blood pressure ($p < 0.0001$), high serum triglycerides ($p < 0.0001$), low HDL ($p < 0.0001$) and abnormal blood pressure ($p < 0.0001$) was significantly higher in VDU users than in controls.

[6] Women who spent more time in front of the screen had a higher percent body fat, but time spent reading did not add to this association. In men it was different: those of a higher educational level who read more had a lower percent body fat. Also, time spent reading by men was a quarter that of screen time, so may not be long enough to contribute to percent body fat, as seen in women.

			using anti-hypertensive medication; fasting glucose ≥ 5.6 mmol/L.		
(Prochaska, et al., 2000)	547 male and female university students, aged 18−29 years, from USA.	Participants completed a questionnaire where they reported the total number of hours spent watching TV in a typical weekday and weekend.	A 7-day physical activity recall interview was used to assess total physical activity and energy expenditure based on reports of time spent in sleep, moderate-, hard- and very-hard-intensity activities. The recall was modified to assess participation in strength and flexibility exercises and to improve its sensitivity to walking. 2 interviews were administered and the results averaged. A questionnaire also assessed time spent in 22 different exercise and sport-related activities, and housework. Measures of health and fitness included resting BP and pulse in triplicate, and 1-min recovery pulse count following completion of a 3-min step test.	*Confounders adjusted for* *Limitations* This was a student group and findings may not be able to be extrapolated to other populations. TV viewing time was the only measure of sedentary behaviour. This was self-reported.	For females, time spent viewing TV was significantly, positively correlated with step-test recovery heart rate and BMI ($p < 0.01$). For males, TV viewing was not significantly correlated with any of the physiological indicators. TV viewing was negatively correlated with vigorous physical activity ($p < 0.01$) and moderate physical activity ($p < 0.01$).
(Proper, Cerin, Brown, & Owen, 2007)	1048 workers from high and low SES neighbourhoods, aged 20−65 years	The self-administered International Physical Activity Questionnaire (IPAQ) was used to assess	BMI was calculated based on self-reported weight and height.	*Confounders adjusted for* Socio-economic factors, working hours, physical activity.	Sitting time on a weekday was significantly negatively associated with occupational physical activity, but not with leisure-time

	from Canberra, Australia.	time spent sitting on weekdays and weekend days over the previous 7 days. Sitting time variables asked about time spent sitting while at work, at home, doing course work, during leisure time, and may include time spent sitting at a desk, visiting friends, reading, or sitting or lying watching TV. Additional questions asked about computer/Internet for leisure, video games, reading, sitting and talking with friends or listening to music, talking on the phone, TV/video viewing, and driving/riding in a car.		*Limitations* Body weight and height were self-reported. Low response rate of 11.5%. Sedentary behaviour was self-reported.	physical activity. Sitting on a weekday and a weekend day was not associated with obesity or overweight. Sitting in leisure time was significantly associated with the risk of being overweight or obese. Compared to those sitting in leisure time < 1170 min, the OR (95% CI) of being overweight/obese was 1.52 (1.11−2.09) and 2.07 (1.47−2.91) for those watching 1170−1859 and ≥ 1860 min/week respectively.
Rosmond et al 1996	1040 males born in 1944, from Sweden.	Participants completed a survey questionnaire which included a question on TV viewing. In terms of the amount of TV viewing, participants responded using a 5-point scale: 1 = never, 2 = seldom, 3 = occasionally, 4 = often, 5 = very often.	Body weight and height were self-reported, and BMI calculated. Participants were instructed how to measure their waist and hip circumference.	*Confounders adjusted for* Waist-to-hip ratio, smoking, alcohol, education and occupation, social variables, leisure-time activities. *Limitations* Only TV viewing was used to estimate sedentary behaviour. This was self-reported. Body weight, height, waist and hip measures were self-reported. All participants were males born in 1944, so the generalisability of results is likely to be limited. The 5-point scale for measuring TV viewing was not	BMI was positively related to TV viewing (p = 0.024). TV viewing was not significantly associated with waist-to-hip ratio after adjusting for BMI.

				specific.	
(Salmon, et al., 2000)	1555 males and 1837 females aged 18 years and over from New South Wales, Australia. Respondents gathered from 1996 state physical activity survey in New South Wales, random selection from White Pages; further random selection of 'next birthday' method.	One question in a telephone-administered questionnaire asked: "How many hours do you spend watching TV and/or videos on a typical weekday?" The question was repeated for a typical weekend day.	BMI was calculated based on self-reported weight and height.	*Confounders adjusted for* Age, sex, education, employment status, physical activity level. *Limitations* Only TV viewing was used to estimate sedentary behaviour. This was self-reported. Body weight and height were self-reported. Modest response rate of 64%.	The likelihood of being overweight increased with increasing hours of TV viewing. Compared to those who watched < 1 h/d of TV, the OR (95% CI) for those watching 1−2.5 h/d, 2.5−4 h/d and > 4 h/d were 1.93 (1.42−2.65) p < 0.0001; 2.83 (1.43−4.62 p < 0.001; and 4.14 (2.04−8.38) p < 0.001, respectively. For all activity levels (low, moderate or high) those watching > 4 h TV/day were twice as likely (OR = 2.0; 2.20 and 2.22 respectively) to be overweight than those watching < 1 h/d (p = 0.005; 0.008 and 0.04 respectively).
(Sanchez-Villegas, et al., 2008)	10,381 participants from a Spanish cohort of university graduates (6-year follow-up).	Participants completed a questionnaire on time spent watching TV and using a computer for both a typical day during the week and weekend. A sedentary index was calculated and categorised into 5 groups: < 10.5 h/week; 10.5−17.49 h/week; 17.5−27.99 h/week; 17.5−27.99 h/week; and ≥ 42 h/week.	Any participant who positively responded to the question "Have you ever been diagnosed with depression/bipolar disorder/anxiety/stress by a health professional?	*Confounders adjusted for* Age, gender, energy intake, smoking status, marital status, arthritis, ulcer, and cancer at baseline. *Limitations* Only TV viewing and computer use were used to assess sedentary behaviour. This was self-reported.	Participants in the highest level of sedentary index showed an increased risk of mental disorder. A direct dose−response relationship between sedentary lifestyles and the incidence of mental disorders was found (p for trend = 0.04). The OR (95% CI) for those who spent > 42 h/week watching TV or using a computer was 1.31 (1.01−1.68) compared with those spending < 10.5 h/week.
(Schaller, et al., 2005)	A nationally representative sample of 365 males and 528 females aged 13−80 years, from	Participants completed 3 unannounced computer-assisted telephone interviews where they were asked to recall the exact type and time spent in activities	For most participants BMI was calculated based on weights and heights measured at health centres (n = 893). The BMI of the	*Confounders adjusted for* Age, sex, energy intake, socio-economic and smoking status. *Limitations*	The use of TV/PC in leisure time was positively associated with obesity. Compared to those in the lowest quintile, the ORs (95% CI) for obesity for those in quintile 2, 3, and 4 were 3.12 (1.42−6.87),

	Bavaria.	including TV or PC use in leisure time.	remaining participants was calculated from self-reported weight and height.	For some participants, body weight and height were self-reported. Only TV/PC use in leisure time was assessed. This was self-reported.	2.92 (1.29−6.58) and 2.51 (1.07−5.87) respectively (p = 0.059 for trend).
(Schmidt, Cleland, Thomson, Dwyer, & Venn, 2008)	787 males and 844 females aged 26−36 years, from Australia.	Participants completed the International Physical Activity Questionnaire (IPAQ), which includes questions on total sitting time. Additional questions were added to assess time spent watching TV/videos/DVDs in the past week.	Waist circumference and skinfold thickness at the tricep, subscapular, bicep, iliac crest, supra-spinal, and mid-abdominal sites were measured. Blood pressure was measured in triplicate. Fasting blood samples were taken to measure insulin, glucose, HDL-C, TC, and TAG. Insulin resistance was estimated by the HOMA index.	*Confounders adjusted for* Age, level of education, marital status, current smoking status, and number of live births. *Limitations* Sedentary behaviour was self-reported.	Of all the measures of sedentary behaviour, TV viewing was a strong and significant predictor of cardiometabolic risk in women but not men. In females, TV viewing was significantly positively correlated with waist circumference ($p < 0.01$), TC ($p < 0.05$), TAG ($p < 0.01$) and HOMA ($p < 0.01$); and negatively correlated with HDL-C ($p < 0.01$), but not correlated with blood pressure. For males, increased sitting time (but not TV viewing) was positively associated with having ≥ 2 cardio-metabolic risk factors (p for trend = 0.02). For females TV viewing (but not sitting time) was positively associated with having ≥ 2 cardio-metabolic risk factors (p for trend < 0.001).
(Shields & Tremblay, 2008)	19,811 males and 22,801 females aged 20−64 years, from Canada. A nationally representative sample (CCHS)	Participants were asked to report the number of hours in a typical week over the past 3 months they spent watching TV/videos, using a computer (including games and Internet), and reading. Respondents were asked to only report leisure-time hours and to exclude time spent on these activities at	BMI was calculated from self-reported weight and height.	*Confounders adjusted for* Age, marital status, education, household income, population size of place of residence, immigrant status, leisure-time physical activity, and daily fruit and vegetable consumption. *Limitations*	TV viewing and computer use were positively associated with the risk of obesity for both males and females. There was no association with reading time and obesity risk. For males, compared to those viewing TV ≤ 5 h/week the ORs (95% CI) for obesity for those viewing 6−10 h/week, 11−14 h/week, 15−20 h/week and ≥ 21 h/week were 1.2 (1−1.5), 1.3

		work or school.		Only leisure-time sedentary behaviour was measured. This was self-reported. Body weight and height were self-reported.	(1.1−1.6), 1.8 (1.5−2.2) and 1.6−2.2 respectively. For females, compared to those viewing TV ≤ 5 h/week, the ORs (95% CI) for obesity for those viewing 6−10 h/week, 11−14 h/week, 15−20 h/week and ≥ 21 h/week were 1.4 (1.2−1.6), 1.4 (1.1−1.6), 1.7 (1.4−2.1), 1.8 (1.6−2.2) respectively. For males, compared to those using computers for ≤ 5 h/week the ORs (95% CI) for obesity for those using computers for 6−10 h/week, and ≥ 11 h/week were 1.2 (10.0−1.4) and 1.2 (1.0−1.4) respectively. For females, compared to those using computers for ≤ 5 h/week the ORs (95% CI) for obesity for those using computers for 6−10 h/week, and ≥ 11 h/week, were 1.3 (1.1−1.5) and 1.3 (1.1−1.6) respectively.
(Sidney, et al., 1996)	4352 Black and White males and females aged 23−35 years. *(the sample was from the CARDIA study)*	Duration of TV viewing was assessed by 2 items in a self-administered questionnaire. Q 1: “During leisure time do you watch TV (a) never, (b) seldom, (c) sometimes, (d) often, (e) very often?” If participants watched TV they were then asked: “On the average, about how many hours per day do you watch TV?”	Physical activity was assessed by an interviewer-administered questionnaire, which assessed the amount of time spent in 13 different activities of either heavy (≥ 5 METS) or moderate (3−4 METS) during the last year. 12 activities were leisure related and 1 related to occupation. Resting BP, height, weight, total	*Confounders adjusted for* Age, education, BMI, physical activity, alcohol use and examination centre. *Limitations* Only TV viewing was used to estimate sedentary behaviour. This was self-reported.	Heavy daily TV viewing (≥ 4 h/d) was significantly associated with a low physical activity score in White men (OR (95% CI) = 2.3 (1.4−3.7), White women = 3.9 (2.3−6.7) and Black women = 1.5 (1.1−2.2). There was no association among Black males. Heavy daily TV viewing (≥ 4 h/d) was significantly associated with a significantly higher risk of obesity in all race/gender groups. The odds ratios ranged from 1.5−2.3 across groups. Heavy TV viewing was significantly

			cholesterol, triglycerides and HDL-C were measured. BMI was calculated from height and weight measure and LDL-C was calculated using the Friedewald equation.		positively associated with LDL-C in Black women only (OR (95% CI) = 3.0 (1.1−8.3). Heavy TV viewing was significantly positively associated with hypertension among White males only (OR (95% CI) = 4.4 (1.6−11.6).
(Spyropoulos, et al., 2007)	157 male and 491 female public office workers in Greece.	Participants completed a self-administered questionnaire including an item on hours of sitting time.	Participants completed a self- administered questionnaire including items on lower back pain (LBP) history, frequency, and duration of episodes. The intensity of LBP was recorded on a VAS at the moment of answering the survey. A participant was recorded as an LBP case if they had experienced pain, ache, or discomfort in their lower back or lower extremities. An orthopaedic physician examined all responses regarding symptoms. A point-prevalent case was referred to an individual who was suffering from LBP at the time of the survey and a 1-year, 2-year and lifetime prevalent case was referred to an individual who was not	*Confounders adjusted for* Age, gender, BMI, ergonomic and psychosocial factors. *Limitations* Sample was a homogeneous group of office workers, predominantly female. Sedentary behaviour was self-reported.	Sitting for > 6 h/d was associated with lifetime prevalence of LBP, OR (95% CI) was 1.588 (10.64−2.386). Sitting time was not associated with point-prevalent LBP, 1-year prevalence LBP, or 2-year prevalence LBP.

			experiencing pain at the time of the survey, but had at least 1 LBP episode previously.		
(Stroebele & de Castro, 2004)	64 female and 14 male under-graduate students; mean (s.d.) age 22 (0.9), from USA.	Participants recorded TV viewing in 15-minute intervals for 7 days.	Nutrient intakes were collected with 7-day diet diaries. Participants were also asked to report whether the TV was on when food was consumed.	*Limitations* Only TV viewing was used to estimate sedentary behaviour. This was self-reported. Participants were all students and mostly female, so the generalisability of the results may be limited.	On average (s.d.), participants reported eating 1.03 (0.07) meals per day with the TV on. There was a significant increase in meal frequency ($p < 0.01$) and a significant decrease in between-meal intervals with TV days ($p < 0.01$). The increased frequency on TV days was associated with a reduction in meal size ($p < 0.01$). However, the increased frequency was greater than the reduced meal size, resulting in an increase in daily intake of carbohydrate ($p < 0.01$) and sugar ($p < 0.05$) on TV days.
(Tucker & Friedman, 1989)	6138 employed males aged ≥19 years, employed by over 50 different companies in the US.	A written questionnaire was administered to assess time spent watching TV per day.	Body composition data were collected by registered nurses. Harpenden skinfold callipers were used to assess subcutaneous fat at the thigh, chest and abdomen. The sum of skinfold measure along with age and sex were used to calculate % total body fat. 21−30% body fat was defined as obese and ≥ 31% body fat as super-obese.	*Confounders adjusted for* Age, fitness, smoking, exercise and hours of work per week. *Limitations* Only TV viewing was used to estimate sedentary behaviour. This was self-reported. The generalisability of the findings is limited to working males.	The relative risk of being obese or super-obese increased as levels of TV viewing increased. Compared with males who watched < 1 h/d, the relative risk of being obese was 1.60 (95% CI: 1.21−2.11); 2.05 (95% CI:1.48−2.84); and 1.90 (95% CI:1.06−3.38) for those who viewed TV for 1−2 h, 3−4 h and > 4 h respectively. Compared with males who watched < 1 h/d, the relative risk of being super-obese was 1.08 (95% CI: 0.51−2.28); and 2.33 (95% CI: 1.18−4.63) for those who viewed TV for 1−2 h and 3−4 h, respectively.
(Tucker &	4771 females with a	A written questionnaire was	Body composition data	*Confounders adjusted for*	Compared with females who

Bagwell, 1991)	median age of 35 years employed by over 30 different companies in the US.	used to collect information on TV viewing.	were collected by registered nurses. Harpenden skinfold callipers were used to assess subcutaneous fat at the thigh, triceps and iliac crest. The sum of skinfold measures along with age and sex was used to calculate % total body fat. Obesity was defined as ≥ 30% body fat.	Age, education, fitness, smoking, exercise and hours of work per week. *Limitations* Only TV viewing was used to estimate sedentary behaviour. The generalisability of the findings is limited as the study population was predominantly White, well-educated, working females.	watched < 1 h/d, the relative risk of being obese was 1.29 (95% CI: 0.99−1.68); 1.89 (95% CI: 1.37−2.61); and 2.15 (95% CI: 1.15−4.01) for those who viewed TV for 1−2 h, 3−4 h and > 4 h, respectively.
(Vioque, Torres, & Quiles, 2000)	A representative sample of 814 males and 958 females aged ≥ 15 years, participating in the Health and Nutrition survey in Valencia, Spain.	Information on TV viewing was collected at household visits using a questionnaire. Participants were asked "How many hours per week do you usually spend watching TV?" The number of hours per day estimated from the response were categorised as: ≤ 1 h/d; 2 h/d; 3 h/d; and ≥ 4 h/d. Participants were also asked to classify their physical activity at work according to 4 categories: (a) sitting most of the day (sedentary); (b) standing most of the day but little motion (moderately active); (c) walking or carrying light weights (active), (d) work requiring intense physical activity (very active). 4 categories of physical activity at leisure time were also used: (a) sitting most of the time	Height and weight were measured during a household visit.	*Confounders adjusted for* Age, sex, population size, marital status, educational level, sleeping time, physical activity, regular practice of sport, smoking status. *Limitations* Sedentary behaviour was self-reported.	Participants viewing TV ≥ 4 h/d had a higher risk of obesity than those viewing ≤ 1 h/d, prevalence OR = 2.38 (95% CI: 1.54−3.69). A significant increasing trend across prevalence ORs was observed. The adjusted prevalence OR of obesity was 30% higher for each additional hour spent viewing TV per day; prevalence OR = 1.30 (95% CI: 1.14−1.48). Participants who were more sedentary at work were at higher risk of obesity than those who were moderately active and active at work ($p = 0.019$). There was no association between leisure-time activity and the risk of obesity.

		(sedentary); (b) walking, gardening, cycling (moderately active); (c) heavier activities – jogging, cycling, tennis (active); (d) athletics or regular sports training (very active).			
(Weiss, Yogev, & Dolev, 1998)	55 clerks (mean [s.d.] age 47.2 [6.6]) and 44 nurses (mean [s.d.] age 48.6 [7.6]) employed for at least 5 years at the E Wolfson Medical Centre, Israel.	Each participant recorded standing/walking time for 1 week.	BMD of the lumbar spine and proximal femur was measured by DEXA.	*Confounders adjusted for* Age, BMI, dietary calcium intake, menopausal state. *Limitations* Sedentary behaviour was assessed by sitting time at work only. This was self-reported.	There was increased hip BMD in nurses whose work demanded standing for considerable amounts of time as compared to clerks who sat most of the day. There was no difference in BMD of the spine between nurses and clerks. The mean age-adjusted BMD at the proximal femur was significantly higher in nurses than clerks ($p = 0.042$). At all sites, age-adjusted femur BMD was positively correlated with the magnitude of standing load.
(Wolin, et al., 2007)	95 Hispanic females aged 40−77 years from Chicago, USA.	Participants completed the International Physical Activity Questionnaire (IPAQ), which assessed the frequency and duration of time spent sitting over the last 7 days.	Percent breast density is a marker of breast cancer. Screening mammography was performed using a full-field digital mammography system. Percent breast density was determined using the NIH ImageJ software.	*Confounders adjusted for* Age, BMI, and smoking status, insulin and HOMA. *Limitations* Results may not be able to be extrapolated to other ethnic groups. Sedentary behaviour was self-reported.	There was a tendency towards a positive association between time spent sitting and percent breast density ($p = 0.06$). There was a 0.25% increase in breast density with each 100-min increase in sedentary time per week.
(Womersley & May, 2006)	20 volunteers from the first-year physiotherapy course at Sheffield Hallam University, UK.	Participants completed an activity diary covering 5-minute intervals over a 3-day period, including 1 weekend day. Time spent sitting per 24-hour period was coded. Participants were	Participants were asked to record any backache by an asterisk in the activity diary.	*Limitations* Small homogeneous sample of physiotherapy students. Sedentary behaviour was self-reported.	Overall there was no significant difference in sitting time between those with and without backache. Those with backache spent significantly more time sitting without interruption in general ($p < 0.024$) and while studying ($p <$

		asked to stipulate the type of activity during periods of sitting (e.g. eating, watching TV, studying). Participants were asked to record any interruption during a period of sustained sitting.			0.014).
Case-control studies					
(Zahm, Hoffman-Goetz, Dosemeci, Cantor, & Blair, 1999)	993 male and 184 female cases of non-Hodgkin's lymphoma (NHL) and 2918 males and 707 female control from Iowa, Kansas, Minnesota and Nebraska.	Occupational sitting time was assessed. Sedentary was defined as > 6 h/d sitting, moderate activity as 2−6 h/d sitting and, high activity as < 2 h/d sitting.	Cases were identified through state cancer registries and a special surveillance of area hospitals	*Confounders adjusted for* Age and state of residence. Cases and control were matched by gender, age, state of residence and vital status. *Limitations* Only occupational sitting time measured to assess sedentary behaviour. This was self-reported.	There were no associations with sitting time and NHL among men or women.
Longitudinal studies					
(Ball, Brown, & Crawford, 2002)	8726 females aged 18-23 years at baseline, from Australia. Participants were followed for 4 years.	Participants completed a self-administered questionnaire completed 4 years after recruitment. Sitting time was assessed by 1 question: "How many hours in total do you typically spend time sitting down while doing things like visiting friends, driving, reading, watching TV, or working at a desk or computer? On a usual week day; on a usual weekend day?" Total sitting time was estimated and divided into tertiles (low sitting time < 33	BMI was calculated from self-reported height and weight.	*Confounders adjusted for* Occupation, student status, martial status, parity and new mothers. *Limitations* Self-reported weights and heights. Results can't be extrapolated to other age groups and males. Sedentary behaviour was self-reported.	Compared with the low sitting group, those who reported moderate (OR: 0.83; 95% CI: 0.73−0.95; p = 0.007) or high (OR: 0.80; 95% CI: 0.70−0.91; p = 0.001) sitting times were less likely to maintain their weight.

		h; moderate sitting time 33−< 52 h; high sitting time ≥ 52 h).			
(Blanck, et al., 2007)	18,583 post-menopausal females aged 40−69 years from USA. Participants were followed for 7 years.	Participants completed a self-administered, mailed questionnaire. Participants were asked: "During the past year, on an average day (not counting time spent at your job), how many hours per day did you spend sitting (watching TV, reading, etc)?" Responses were categorised into tertiles: < 3 h/d; ≥ 3−5 h/d; ≥ 6 h/d.	Participants' weights were self-reported at baseline and follow-up. Weight gain was defined as the difference in weight between the 2 time periods.	*Confounders adjusted for* Age, recreational physical activity, education, smoking status, hormone therapy use, total energy. *Limitations* Self-reported weight. Occupational sedentary behaviour was not assessed. Sedentary behaviour was self-reported.	Sedentary behaviour was not associated with a 5- to 10-pound weight gain. Among women who were not overweight at baseline, the odds of ≥ 10-pound gain were 47% higher (OR: 1.47; 95% CI:1.21−1.79), for those who reported ≥ 6 h/d of non-occupational sedentary behaviour, and 16% higher (OR:1.16; 95% CI:1.04−1.28) for those who reported 3−5 h/d of sedentary behaviour, compared to < 3 h/d. Sedentary behaviour was not associated with risk of ≥ 10-pound gain among women who were overweight at baseline.
(Boone, Gordon-Larsen, Adair, & Popkin, 2007)	9155 adolescents (4879 males and 4276 females) aged 13−20 years from USA. Participants were followed for 6 years.	Participants completed self-administered in-home surveys. Screen time was defined as hours of TV and video viewing per week.	Participants' weights were self-reported at baseline and follow-up, from which BMIs were calculated.	*Confounders adjusted for* Age, ethnicity, household income, parental education, season, smoking status, and geographic region. *Limitations* Only screen time was measured to represent sedentary behaviour. This measure of sedentary behaviour was self-reported. Body weight and height were self-reported.	For both males and females screen time during adolescence was a significant predictor of obesity (p = 0.043), as was an increase in screen time from adolescence to early adulthood (p = 0.021).
(Brown, et al., 2005)	8071 females aged 45−55 years from the Australian Longitudinal Study	Estimated sitting time was calculated from 2 questions about sitting during weekdays and weekend days	Participants' weights and heights were self-reported at baseline and follow-up. BMI was	*Confounders adjusted for* Habitual physical activity, smoking transition, menopause transition,	Average weight gain over 5 years was significantly lower than the sample average among women who reported sitting for < 3 h/d (p

	on Women's Health. Participants were followed for 5 years.	asked during the final survey at year 5 only. Questions asked about time spent sitting while doing things like visiting friends, driving, reading, watching TV, or working at a desk or computer. Average sitting time was categorised into quintiles: very low: < 3 h; low: 3− < 4.5 h; moderate: 4.5−< 6 h; high: 6−< 8 h; very high: ≥ 8 h).	calculated. 5-year weight gain was defined as the difference in weight between the 2 time periods. Weight gain was categorised into 5 groups (maintainer: -2.25−+2.25 kg; weight loser: >−2.25 kg; low gainer: > +2.25−5 kg; moderate gainer: > 5−10 kg; high gainer: > 10 kg).	energy intake, body weight. *Limitations* Self-reported weights and heights. Sitting time was only estimated at the final survey. Sedentary behaviour was self-reported.	< 0.0001). Weight gain was significantly higher among women who reported sitting time > 8 h/d (3.04 kg, 95% CI: 2.71−3.38) compared with those who sat for < 3 h/d (1.80 kg, 95% CI: 1.50−2.11), (p < 0.0001). Women reporting > 4.5 h/d of sitting time were more likely to gain > 5 kg than those reporting < 3 h/d of sitting time (p < 0.05).
(Ching, et al., 1996) (*also see cross-sectional data from this study above)*	22,076 males aged 40−75 years, from the Health Professionals Follow-up Study in the USA. *Data from the Health Professionals Follow-up Study*	Participants completed a self-administered, mailed questionnaire in 1988 and 1990. Time reported watching TV/videos each week was the indicator of sedentary behaviour. Participants were placed within 1 of 6 time categories (0−1 hours; 2−5 hours; 6−10 hours; 11−20 hours; 21−40 hours; ≥ 41 hours).	Self-reported body weight and height from questionnaires completed in 1988 and 1990 were used to calculate BMI.	*Confounders adjusted for* Age, smoking status, quintile of non-sedentary activity level. *Limitations* Short follow-up (2 years). Only TV viewing was used to estimate sedentary behaviour. This was self-reported. Body weight and height were self-reported. The findings are limited to middle- to older-aged males of relatively high SES.	The cumulative incidence of overweight tended to increase with increasing time spent watching TV/videos in 1988. However, none of the estimated relative risks for each time category reached significance, although the test for trend across relative risks was significant (p = 0.002). The relative risks of being overweight for those watching 20−41 hours and ≥ 41 hours of TV/video were 1.41 (95% CI: 0.94−2.21) and 1.49 (0.57−3.95) respectively, compared to those watching less than 1 h/week. Each 10 h/week increase in TV/video viewing predicted a 0.05 increase in BMI and a 0.15 kg weight gain between 1988 and 1990. TV/video viewing and the odds of being overweight were independent of physical activity levels.

(Coakley, Rimm, Colditz, Kawachi, & Willett, 1998)	19,478 males aged 40−75 years in 1986 from the Health Professionals Follow-up Study in the USA. *Data from the Health Professionals Follow-up Study*	Participants completed a self-administered, mailed questionnaire in 1988 and 1992. Time reported watching TV/videos each week was the indicator of sedentary behaviour.	Self-reported body weight and height from questionnaires completed in 1988 and 1992 were used to calculate BMI.	*Confounders adjusted for* Baseline weight, height, vigorous activity, high blood pressure and high blood cholesterol levels. *Limitations* Only TV viewing was used to estimate sedentary behaviour. This was self-reported. Body weight and height were self-reported. The findings are limited to middle- to older-aged males of relatively high SES. Caloric intake was not controlled for.	For males aged 45−54 years, TV/video viewing was positively related to weight gain ($p < 0.01$). A 10 h/week increase in TV/video viewing was associated with approximately a 0.2 kg increase in body weight over 4 years. This relationship was independent of the association between body weight and physical activity. For males aged ≥ 55 years, TV/video viewing was not a significant predictor of weight gain. Compared to males who maintained a high level of TV/video viewing, those who increased their viewing gained on average 1.2 k g over 4 years.
(Crawford, et al., 1999) *(see cross-sectional data above)*	176 males, 428 high-income females and 277 low-income females, aged 20−45 years, from Australia.	At each assessment participants were asked to report how many hours of TV they watched on an average day. Average daily TV viewing for each participant during the study period was calculated, as well as the change in TV viewing over the study period.	Body weight was measured at baseline and during 3 annual follow-up assessments. BMI was calculated.	*Confounders adjusted for* Baseline BMI, treatment group, age, education, baseline smoking, energy intake, percentage energy from fat. *Limitations* Only TV viewing was used as a measure of sedentary behaviour. This was self-reported. Low-income men were not part of the cohort.	There were no significant relationships between change in BMI and TV viewing among the 3 groups.
(Fung, et al., 2000)	468 male US health professionals aged 40−75 years. *A sub-sample of the Health Professionals*	TV and video viewing was assessed by a questionnaire biennially starting in 1988. In 1988 the questionnaire included 6 response categories ranging from 1−2	Participants provided a blood sample between 1993 and 1994. Blood was analysed for TC, LDL-C, HDL-C, TAG, Apo A1, insulin, C-peptide, HBA1c,	*Confounders adjusted for* Age, alcohol intake, total dietary fibre, saturated fat, polyunsaturated fat, and smoking. *Limitations*	The number hours of TV viewing were inversely associated with HDL-C ($p < 0.01$) and ApoA1 ($p < 0.05$) and positively associated with LDL-C ($p < 0.05$) and leptin ($p < 0.05$). These associations were independent of physical

	Follow-up Study.	h/week to ≥ 40 h/week. Subsequent questionnaires included 13 categories ranging from 0 to ≥ 40 h/week.	fibrinogen, and leptin. Body weight was assessed biennially and BMI calculated.	Only TV viewing was used to estimate sedentary behaviour. This was self-reported. The sample was health professionals and therefore results may not be generalisable to other populations.	activity.
(Howard, et al., 2008)	292,069 males and 196,651 females aged 50-71 years from the USA.	Participants collected a questionnaire including information about the average number of hours per day currently spent watching TV or videos, and the average number of hour per day spent sitting.	The incidence of colon and rectal cancers was histologically confirmed.	*Confounders adjusted for* BMI, age, smoking, alcohol consumption, education, race, family history of colon cancer, total energy and energy-adjusted intake of red meat, calcium, whole grains, fruits and vegetables, total physical activity; and, for women, menopausal hormone therapy. *Limitations* Sedentary behaviour was self-reported.	For males there was a significant increase in the risk of colon cancer with more time spent watching TV/videos. Compared to 3 hours of watching TV/videos, watching ≥ 9 h/d was associated with a relative risk (95% CI) for colon cancer of 1.56 (1.11−2.20), p = 0.002). Compared to sitting < 3 h/d, the relative risk (95%CI) of colon cancer for ≥ 9 h/d of sitting was 1.22 (0.96−1.55), p = 0.073). For females, increasing time spent watching TV was statistically significantly associated with increased colon cancer risk in the age-adjusted models only (p = 0.002). This trend was not significant in the multivariable-adjusted model. There was no significant associations with time spent sitting and colon cancer risk in women.
(Hu, et al., 2001)	37,918 males aged 40−75 years, from the US Health Professionals Follow-up Study.	Participants completed biennial questionnaires where they reported their average weekly time spent watching TV/video.	If participants reported they had been diagnosed with diabetes in the biennial questionnaire, a supplementary	*Confounders adjusted for* Age, time periods, cigarette smoking, parental history of diabetes, alcohol consumption, saturated fat, monounsaturated fat,	Average time spent watching TV was strongly associated with increased risk of diabetes. The relative risks across categories of average hours spent watching TV per week (0−1, 2−10, 11−20,

			questionnaire regarding symptoms, diagnostic tests and hypoglycaemic therapy was mailed to them. A case of diabetes was confirmed if at least 1 of the following was reported: (1). One or more classic symptoms plus 1 fasting glucose ≥ 7.8 mmol/L or ransom glucose ≥11.1; (2). At least 2 elevated glucose concentrations on different occasions in the absence of symptoms; (3). treatment with hypoglycaemic medication.	polyunsaturated fat, trans-fatty acids, cereal fibre, physical activity and BMI. *Limitations* TV viewing was the only measure of sedentary behaviour. This was self-reported. This is a sample of health professionals which may limit the generalisability of the results	21−40 and > 40) were 1.00, 1.49, 1.39, 1.77, 2.23; p-value for trend = 0.02.
(Hu, Li, Colditz, Willett, & Manson, 2003)	68,497 women aged 30−55 years from the Nurses Health Study, followed from 1992 to 1998 in the USA. At 1992 all women were free of diabetes and 50,277 had a BMI < 30.	Participants self-reported in a questionnaire their average weekly time spent sitting at home while watching TV or VCR, sitting at work or away from home or while driving, and other sitting at home (e.g. reading, meal times, at desk).	Body weight self-reported, incidence of obesity was a transition to a BMI ≥ 30. Women who said they had been diagnosed with diabetes were sent a separate questionnaire for confirmation of diagnosis (reported blood tests or treatment with medication).	*Confounders adjusted for* Age, smoking, alcohol consumption, and physical activity, total energy intake, total fat, glycaemic load and cereal fibre, trans fat, polyunsaturated fat, family history of diabetes	Time spent TV watching was positively associated with risk of obesity across the categories of TV watching (0−1, 2−5, 6−20, 21−40, > 40 h/week) in a dose−response manner (RR = 1.0, 1.23, 1.42, 1.68 and 2.00) (p for trend < 0.001). Sitting at work, sitting away from home, and driving were also significantly associated with increased risk of obesity. Average time spent watching TV across the categories of TV watching was significantly associated with increased risk of type 2 diabetes (RR = 1.0, 1.10,

					1.30, 1.53 and 1.98) (p for trend < 0.001). Sitting at work and other sitting at home (last category only) were both associated with significantly increased risk of diabetes in multivariate analyses adjusting for all covariates. For each 2 h increase in watching TV, there was a 23% (95% CI: 17−30%) increase in obesity risk. In contrast, other sitting at home for each 2 h increase was significantly associated with a lower risk of obesity (data not supplied). For each 2 h increase in watching TV, there was a 14% (95% CI: 5−23%) increase in diabetes risk. Those who were in the lowest tertile of physical activity and highest tertile of TV watching had the highest levels of risk of obesity and diabetes. 30% of new obesity cases and 43% of new diabetes cases were attributable to the effects of 2 risk factors. *Either* > 10 h/week of TV, *or* < 30 min/d walking (or equivalent).
(Jeffery & French, 1998) *(also see cross-sectional data from this study above)*	198 males and 529 females with high-income and 332 low-income females; aged 20−45 years; from USA.	TV viewing was assessed by 1 item in a questionnaire: "On an average day, how may hours of TV do you watch?"	Body weight was measured in light clothing and height was recorded. BMI was calculated from these height and weight measurements.	*Confounders adjusted for* Age, education, baseline smoking, baseline BMI, BMI, treatment group. *Limitations* A short prospective period	A marginally significant positive relationship was found between TV viewing and change in BMI in high-income females only.

				of 1 year. Only TV viewing was used to estimate sedentary behaviour. This was self-reported. Population were specifically high-income men and women and low-income women, so results may not be able to be extrapolated to low-income males and middle-income groups. Generalisability is also limited because the sample was composed of volunteers for a weight-gain-prevention trial.	
(Katzmarzyk, Church, Craig, & Bouchard, 2009)	Representative sample of 17,013 Canadians 18−90 years of age.	This was a 14-year follow-up of the 1981 intake of the Canadian Fitness Survey (CFS).	Measures of sitting time, PA (self report) and mortality from all causes, CV death, and death from cancer.	*Confounders adjusted for* Physical activity, age, sex, smoking and alcohol consumption.	There had been 1832 deaths (759 of cardiovascular disease [CVD] and 547 of cancer) at follow-up. There was a progressively higher risk of mortality across higher levels of sitting time from all causes (hazard ratios [HR]: 1.00, 1.00, 1.11, 1.36, 1.54; p for trend < 0.0001) and CVD (HR:1.00, 1.01, 1.22, 1.47, 1.54; p for trend < 0.0001) but not cancer. Similar results were obtained when stratified by sex, age, smoking status, and BMI.
(Leitzmann, et al., 1998)	45,813 male health professionals (dentists, veterinarians, pharmacists, optometrists, osteopathic physicians, and podiatrists) in USA	Cohort followed from 1986 to 1994 with bi-annual surveys. Self-reported survey of TV watching.	Self-reported cholecystectomy (surgical removal of the gallbladder) or received diagnosis of gallstones from a physician.	*Confounders adjusted for* Controlled for BMI at age 21, age, history of diabetes mellitus, smoking, cholesterol-lowering drugs, thiazide diuretics, non-steroidal anti-inflammatory drugs, alcohol, energy-adjusted dietary fibre,	Men who watched more than 40 h of TV/week were 2.53 times more likely to have gallstone disease (95% CI: 1.38−5.18, p < 0.02) than men who watched < 6 h TV/week.

	who were 40−75 years old in 1986.			energy-adjusted carbohydrates and physical activity. *Limitations* Possibilities that the symptoms of latent gallstone disease could have induced a reduction in physical activity, biasing the results. This was controlled for by excluding the first 2-year follow-up period. Participants were not systematically screened for the presence of gall stones by using ultrasonography or other imaging tests. Most cases of gallstones are asymptomatic.	
(Leitzmann, et al., 1999)	60,290 female registered nurses (aged 66.3) from the US Nurses' Health Study. Demographic details (BMI, parity, diabetes, smoking etc) not available for this particular data set. Baseline reported data for 1986.	Cohort undertaken with questions around inactivity between1990 and 1996. 1992 questions around TV watching were included. Weekly physical inactivity score (MET hr/week) based on average time sitting at work or while driving, as well as time spent watching TV.	Self-reported cholecystectomy (surgical removal of the gallbladder) and date of operation (validated in a small random sample of 50 nurses).	*Confounders adjusted for* BMI, weight change in previous 2 years, age, parity, use of oral contraceptives, use of post-menopausal hormones, history of diabetes mellitus, pack-years of smoking; use of cholesterol-lowering drugs, use of thiazide diuretics, use of non-steroidal anti-inflammatory drugs, intake of energy-adjusted dietary fibre, energy-adjusted carbohydrates, alcohol, and coffee, BMI, recreational physical activity.	Compared with women who spent less than 6 h/week sitting while at work or driving, women who spent more than 61 h/week sitting were 2.18 times more likely to have gallstone disease (95% CI: 1.19−4.01). The relative risk associated with watching > 61 hours of TV/week and gallstone disease was non-significant after controlling for body weight and recent changes in body weight (RR = 1.12; 95% CI: 0.78−1.58) (p = 0.3).

				Limitations No information testing sedentary self-reported behaviour was undertaken.	
(Levine, et al., 2008)	15 healthy, sedentary obese (BMI 30−35) subjects, non-smoking, not pregnant, no acute or chronic illness, steady body weight (< 2 kg fluctuation in 6 months prior to study), no history of thyroid malfunction and not taking drugs capable of altering metabolic rate. 14 women and 1 man; average age 43 years.	Energy expenditure measured for 20 minutes while lying motionless, sitting in an office chair, standing motionless, walking at 1, 2 and 3 miles per hour, and using a vertical workstation with a treadmill at a self-selected speed.	Used indirect calorimeter to measure energy expenditure. Test−retest differences for duplicate basal metabolic rate were < 3%.	*Limitations* Short duration of study so did not test whether weight loss actually occurs. 15 participants, most were women.	Sitting: 65 kcal/h; standing still: 82 kcal/h; walk and work desk 1.1 mph: 191 kcal/h. Mean self-selected speed of walk at work desk was 1.1 mph, with a difference of 119 kcal/h above sitting in an office chair. Use of 2−3 h/d by an obese worker would, if other components of energy balance were constant, lead to a weight loss of > 20 kg/year. Participants enjoyed using the desk, and there were no falls or injuries.
(Patel, Rodriguez, Pavluck, Thun, & Calle, 2006)	59,695 women with a mean age of 62.7 years at study entry (1992). Drawn from the CPS-II Nutrition Cohort, comprising 97,786 women.	Baseline self-administered questionnaire asked participants: “During the past year, on an average day (not counting time spent at your job) how many hours per day did you spend sitting (watching TV, reading etc?”	Self-report on a follow-up questionnaire and subsequent verification from medical record or linkage with state cancer registries. Interval deaths via the National Death Index where ovarian cancer was listed as the primary or contributory cause of death. Medical and registry records were checked for additional information to verify ovarian cancer.	*Confounders adjusted for* Adjusted for age, recreational physical activity, race, BMI, family history of breast and/or ovarian cancer, age at menopause, age at menarche, oral contraceptive use, parity, hysterectomy, post-menopausal hormone replacement therapy use. *Limitations* Self-completed questionnaire. No objective measurement of exposure.	Women who sat for > 6 h/d at baseline were 1.55 times more likely to contract ovarian cancer than women who sat for < 3 h/d at baseline (OR = 1.55, (95% CI: 1.08−2.22).

(Patel, et al., 2008)	42,672 women with a mean age of 62.8 years at study entry (1992). Drawn from the CPS-II Nutrition Cohort, comprising 97,786 women.	Baseline self-administered questionnaire asked participants: “During the past year, on an average day (not counting time spent at your job) how many hours per day did you spend sitting (watching TV, reading etc?”	Self-report on a follow-up questionnaire and subsequent verification from medical record or linkage with state cancer registries. Interval deaths via the National Death Index, where endometrial cancer was listed as the primary or contributory cause of death. Medical and registry records were checked for additional information to verify endometrial cancer.	*Confounders adjusted for* Adjusted for age, smoking, total energy intake, BMI, personal history of diabetes, age at menopause, age at menarche, oral contraceptive use, hysterectomy, post-menopausal hormone replacement therapy use.	Further adjustment for BMI altered the relationship between endometrial cancer and sedentary behaviour (6+ versus < 3 h/day sitting time, RR = 1.4; 95% CI: 1.03−1.89), making it non-significant (6+ versus < 3 h/day sitting time, RR = 1.18; 95% CI: 0.87−1.59)
Intervention studies					
(Levine, et al., 2005)	20 healthy volunteers self identified as “couch potatoes”. 10 participants were lean (BMI 23) and 10 were obese (BMI 33). Obese subjects were not incapacitated by joint problems or other medical conditions.	10 days of continuous physical activity movement data from inclinometers and accelerometers. Total non-exercise activity thermogenesis (NEAT) measured by stable isotope technique. In this case NEAT = total energy expenditure as participants are “couch potatoes”. BMI, measured height and weight. Sitting time calculated from inclinometers and accelerometer data. Asked 7 of the original obese to undergo 8-week weight loss, with an average loss of 8 kg. Overfed 9 of the original lean (+ 1 new participant) for 8 weeks, with an average weight gain of 4 kg. After the weight changes, another 10 days of movement data were collected.		*Limitations* Short-term overfeeding and weight loss	Obese participants were seated for 164 min longer per day than lean participants, and lean participants were upright for 152 min longer per day than obese participants. Sleep times were almost identical between the groups. Both obese subjects losing weight and lean subjects gaining weight maintained their original times spent sitting and standing. In this study, between-individual differences in the time spent sitting and standing were biologically determined.

Notes: BMD = bone mineral density; BMI = body mass index; BP = blood pressure; CCHS = Canadian Community Health Survey ; CI = confidence interval; CVD = cardiovascular disease; d = day; FBG = fasting blood glucose; h = hour; HDL-C = high-density lipoprotein cholesterol; HOMA = homeostasis model assessment; LBP = lower back pain; LDL-C = low-density lipoprotein cholesterol; min = minute; n = number; MONW = metabolically obese but normal weight; NCEP = National Cholesterol Education Program; NHANES = National Health and Nutrition Examination Survey; OGTT = oral glucose tolerance test; OR = odds ratio; p = p-value (probability); PC = personal computer; PG =

plasma glucose; RR = relative risk ; s.d. = standard deviation; TC = total cholesterol; TAG = triglycerides; TV = television; WHO = World Health Organisation; yr = year.