Public Health Devon

Devon County Council

Leisure-time Sedentary Behaviour in Adults Evidence Review

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Contents

1. Executive Summary

1.1 The word 'sedentary' is derived from the Latin verb 'sedere' meaning 'to sit'. The British Heart Foundation (2012) defines the term as, 'a group of behaviours that occur whilst sitting or lying down while awake and typically require very low energy expenditure'.

1.2 The last 10 years has seen a growth in research exploring the association of sedentary behaviour with various health outcomes. These behaviours (typically in the context of TV viewing, computer and game-console use, workplace sitting and time spent in cars) have emerged as a new focus for research into physical activity and health. This report summarises the literature and explores interventions to reduce sedentary behaviour in adults.

1.3 After searching the literature, 46 papers were identified for review. This included four systematic reviews, randomised controlled trials, observational studies, commentaries and reviews, qualitative studies, experimental trials and Government reports.

1.4 There is much evidence to indicate an increasing risk of negative health outcomes with increasing sedentary behaviour. The literature suggests that high levels of prolonged sedentary time, **independent of the time spent in moderate or vigorous intensity physical activity**, is associated with worse health outcomes including type 2 diabetes, cardiovascular disease, metabolic syndrome and obesity (Dunstan, 2010).

1.5 Prince et al. (2014a) argue that there is a gradient effect, where the risks for morbidity and mortality are higher in those people engaging in higher levels of sedentary behaviour.

1.6 Public Health England (2014) states that more than 40% of women and 35% of men spend over six hours a day desk-bound or sitting still. The highest levels of sedentary behaviour are seen in those aged 16-24 and aged 65 and over, with sedentary time increasing at the weekend compared to weekdays (Health Survey for England, 2012).

1.7 It is not just total sedentary time that is important, but the pattern by which it is accumulated. In the Australian Diabetes, Obesity and Lifestyle survey (AusDiab) Healy et al. (2008) found that a higher number of breaks (i.e. frequent interruptions to sedentary time) were beneficially associated with waist circumference, BMI, triglycerides (a type of fat found in the blood) and 2-hour plasma-glucose (a marker of diabetes risk).

1.8 It is unlikely that adults are very conscious of the problems associated with high levels of sedentary behaviour, as well as how long they spend in sedentary behaviours each day.

1.9 It is possible for an individual to meet the Chief Medical Officer's (CMO) recommendations for physical activity, *and* spend a prolonged time in sedentary behaviours, which Hamilton (2008) terms as the 'Active Couch Potato'.

1.10 Sedentary behaviour is complex with numerous determinants in different settings, and should be treated as a separate behaviour in its own right. The

ecological model approach describes multiple levels of influence including individual, social, organisational/community, environmental and policy. It is important to influence and advocate for environment, transport and planning policy which can create environments to facilitate less sedentary behaviour.

1.11 Published interventions observing changes in sedentary behaviour as a measured outcome generally fall into four categories; (i) physical activity interventions, (ii) physical activity and sedentary behaviour interventions, (iii) sedentary behaviour interventions and (iv) lifestyle interventions.

1.12 Two systematic reviews undertook meta-analyses, whereby data is pooled from a number of randomised controlled trials to increase statistical power. They concluded that interventions to reduce sedentary behaviour as the primary outcome (as opposed to increasing physical activity) had the most significant reduction effects out of all the intervention types. However, these conclusions are based on 8 studies, only one of which was in a leisure/home setting, with the remaining studies being set in the workplace. This limits their external validity to other populations and highlights the need for further research to establish if meaningful reductions in sedentary time can be observed in settings such as in the home.

1.13 Interventions with a focus on increasing physical activity or that included a physical activity or sedentary component produced less consistent findings. One of the systematic reviews found evidence of small reductions in sedentary behaviour (which were statistically significant) in the interventions studied, whilst the other review found no evidence of statistically significant reductions in sedentary behaviour. This highlights the need to treat sedentary time as a behaviour in its own right, separate but related to physical activity.

1.14 Smart-phone applications (apps) may offer some promise in providing cost-efficient ways to reach and prompt behaviour change such as interrupting sedentary behaviour. Further high quality research is needed into the on-going sustainability and suitability of this type of approach.

1.15 Some authors argue that light intensity activity can have some potential health benefits; Healy et al. (2008) report that, ‘light intensity activity has an inverse relationship with a number of cardio-metabolic markers’.

1.16 For people who are not regularly active, reducing sedentary behaviour and increasing light intensity activity may be a more achievable goal for increasing movement and energy expenditure, as a first step on the way to being more active. Moving the most inactive people to a significant level of activity would have the greatest benefit, but any shift helps (Public Health England, 2014).

1.17 Public health messages should raise the importance of reducing and interrupting sedentary behaviours *alongside* the benefits of being physically active as part of any physical activity or lifestyle intervention.

2. Introduction

Background

2.1 This literature review has been carried out to inform several Public Health work streams including the physical activity work plan, the new Healthy Lifestyle service, the emerging Healthy Lifestyle Strategy and the Joint Commissioning Strategy for Prevention. The intention is to provide a review useful to a range of stakeholders including commissioners, policy makers and providers of community, lifestyle and physical activity services.

2.2 Evidence will also inform the content for a digital social norming consumer campaign as part of the social marketing work plan, designed to promote and normalise more active behaviours as part of an individual's everyday life.

Context

2.3 The physical, social and economic environments in which individuals live and work have changed rapidly in the last 50 years. Technological advances in transportation, communications, work place and domestic-entertainment environments have reduced the demands for physical activity.

2.4 Sedentary behaviours (typically in the context of TV viewing, computer and game-console use, workplace sitting and time spent in cars) have emerged as a new focus for research into physical activity and health.

2.5 There is a good deal of evidence already published on reduction of sedentary behaviours in the workplace, however, fewer studies have focused on reducing sedentary behaviours in the home/during leisure time. It is for this reason that leisure sedentary behaviour is the subject of this literature review.

2.6 Sedentary behaviour interventions have been conducted with children for some years but those with adults are much more recent (Garner et al., 2015). This is despite the evidence that adults spend a considerable amount of time in sedentary leisure pursuits (Rhodes et al., 2012); this review will therefore focus on adults as the population group.

3. Search Strategy

3.1 The research questions for this review are:

- What are the influences and factors associated with leisure-time sedentary behaviour in adults (sections 5 & 7)
- What are the facilitators and barriers to changing leisure-time sedentary behaviour in adults (section 6)
- What is the evidence for effective interventions to reduce leisure-time sedentary behaviours in adults (section 8)

3.2 A variety of databases were searched:

CINAHL
MEDLINE

NIHR Library
Ovid online (EMBASE and Amed)
Pub Med
Ingenta Connect
Cochrane
NICE Healthcare Databases

3.3 The results of individual database searches are shown at Appendix 1, along with selected search terms. NHS Evidence was searched for evidence summaries and guides, health technology assessments and research protocols. Reference lists were studied for further sources.

3.4 The PICO method of structuring a search strategy was used:

Population: Adult population exhibiting sedentary behaviours in their leisure time
Intervention: Influences on or determinants of sedentary behaviour, effective interventions tackling sedentary behaviour, facilitating factors which support behaviour change in this context
Comparison: N/A
Outcomes: Less sedentary, understanding of behavioural determinants which could influence a reduction in sedentary behaviour, effective interventions.

3.5 Abstracts were reviewed to determine relevance against the following exclusion criteria:

- Study not available in English language
- Study taken place in a developing country
- Study taken place in a workplace setting
- Study focusing on sports-based interventions
- Study purely reporting on physical inactivity (defined as less than 30 minutes of activity a week)

3.6 Forty-six papers and reports were identified (focusing on adults), including four systematic reviews (two of which were meta-analyses), as well as a mixture of Randomised Controlled Trials (RCTs), observational studies, commentaries, reviews, qualitative studies, experimental trials and national reports.

3.7 Some studies involved small sample sizes, which may limit the generalisability of their results to a larger population, but are included in this review to demonstrate some of the new thinking and design around interventions to break up sedentary behaviour. The studies are principally from the UK, Australia, Belgium, Spain, the US and Canada.

4. What is 'Sedentary Behaviour'?

Definition of Sedentary Behaviour

4.1 The English word sedentary is derivative of the Latin verb 'sedere' meaning 'to sit' and sedentary behaviours are defined both in terms of a postural description and their low energy expenditure.

4.2 The British Heart Foundation further defines the term, describing it as 'a group of behaviours that occur whilst sitting or lying down while awake and typically require very low energy expenditure' (British Heart Foundation, 2012).

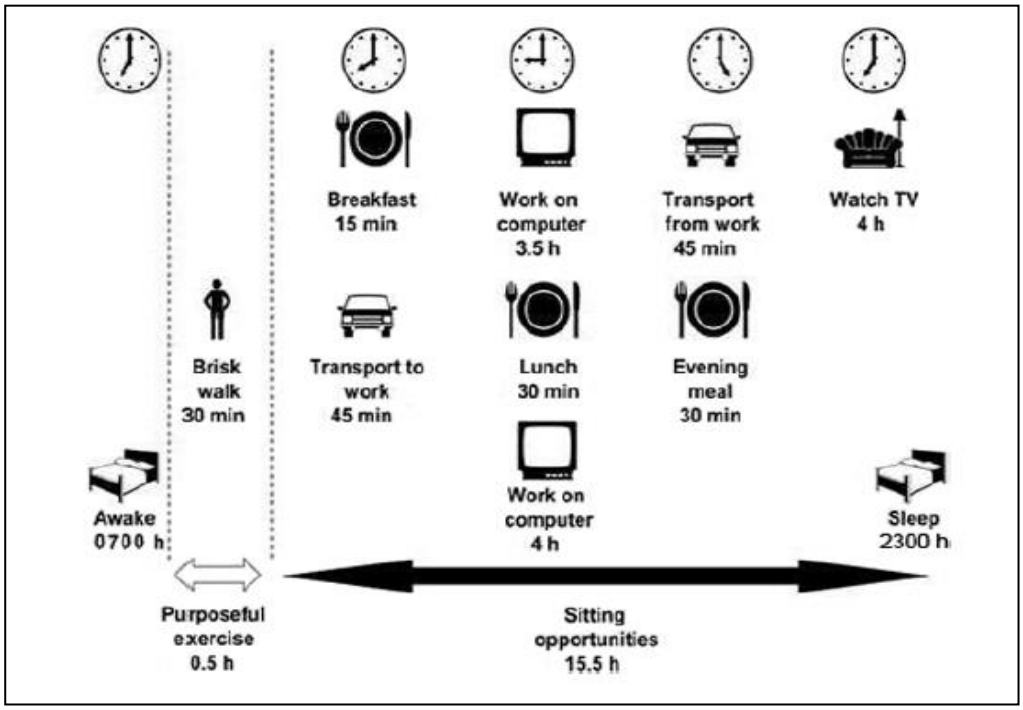
4.3 In 2011 the Chief Medical Officer's report, 'Start Active, Stay Active' provided recommendations on sedentary behaviour as part of the new Physical Activity Guidelines. The report recommends that adults and children should *minimise* the amount of time spent sedentary for long periods. The report also states that there are not enough data to provide a specific quantitative recommendation on daily limits for sedentary time.

Distinction between Physical Activity and Sedentary Behaviour

4.4 It is important to distinguish that sedentary behaviour is not simply a lack of physical activity. It is defined as behaviour in its own right.

4.5 It is possible for individuals to meet the Chief Medical Officer's recommendations for physical activity (DH, 2011) and also spend long periods of time engaged in sedentary behaviour (known as the 'active couch potato', Hamilton et al. 2008). For example, an 'active' individual may engage in 30 minutes a day of brisk walking or jogging and meet the guidelines, however this leaves up to 15½ waking hours where time spent sitting, standing or doing light intensity activities could vary enormously. Figure 1 illustrates the ubiquitous nature of sedentary time.

Figure 1 – Contexts for sedentary behaviour and their distribution over a typical adult's waking hours (From Dunstan et al. 2010)



4.6 It should not be assumed that increased physical activity *automatically* leads to less sedentary time. Gardner et al. (2015) reviewed 38 behaviour change interventions and concluded that reduced sedentary behaviour is not an inevitable consequence of effective physical activity interventions.

4.7 Temblay et al. (2010) argue that reducing sedentary behaviour can be achieved 'through almost limitless micro-intervention opportunities designed to promote energy expenditure'. In addition, this can be achieved with minimal/no cost or time constraints. Physical activity may be perceived as having more constraints such as time, location, cost, equipment and logistics; which present potential barriers to behaviour change.

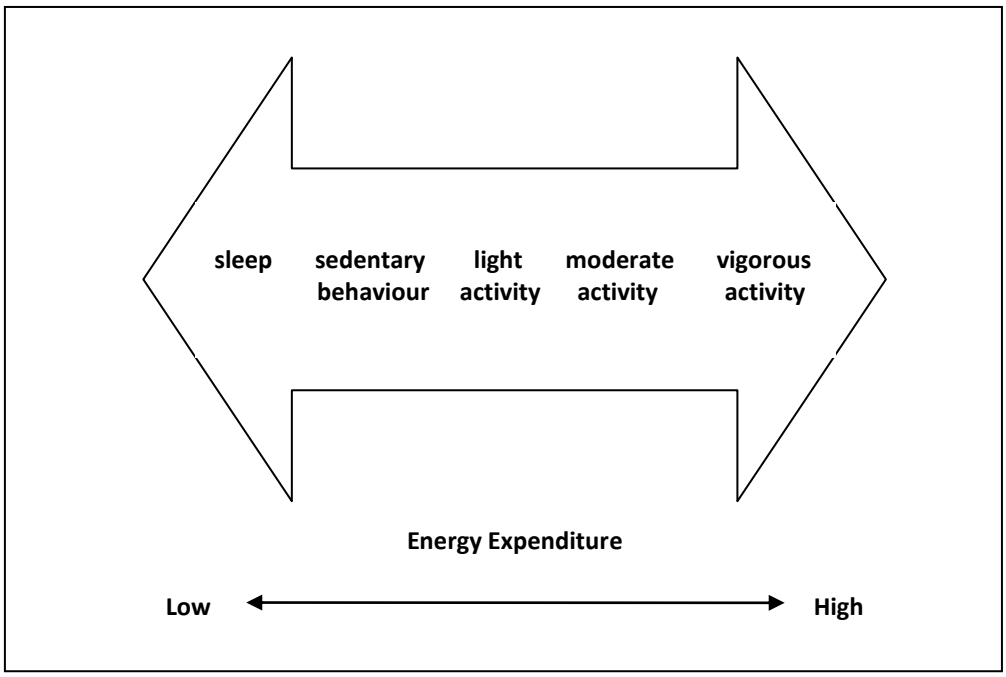
4.8 For people who are not regularly active, reducing sedentary behaviour and increasing light intensity activity may be a more achievable goal for increasing movement and energy expenditure, as a first step on the way to being more active. Moving the most inactive people to a significant level of activity would have the greatest benefit, but any shift helps (Public Health England, 2014).

4.9 The effectiveness of physical activity interventions is well evidenced. It is not clear whether these interventions can produce 'clinically significant' reductions in sedentary behaviour, or how large a reduction is needed to be 'clinically significant'. Prince et al. (2014a) note that individuals who increase their level of physical activity may even become more sedentary for the rest of the day if they feel satisfied that they have achieved their recommended minimum level of physical activity.

Energy Continuum

4.10 In terms of a continuum of activity, it is helpful to consider relative energy expenditure as illustrated in Figure 2. Sedentary behaviour is defined as any waking behaviour with an energy expenditure ≤ 1.5 Metabolic Equivalent of Task (METs) (Prince et al., 2014a) while in a sitting or reclining posture.

Figure 2 – Human movement and energy expenditure continuum (adapted from Tremblay et al. (British Heart Foundation, 2010)



4.11 In this context 1 MET corresponds to a resting metabolic rate. Sedentary behaviours such as TV viewing, computer use, or sitting in a car are in the low

energy expenditure range of between 1.0 to 1.5 METs. To put this into context, moderate to vigorous physical activity, such as cycling, swimming, walking or running, requires an energy expenditure of between 3 to 8 METs. Light intensity activities are those done whilst standing and generally require energy expenditure of no more than 2.9 METs (Owen et al., 2010).

4.12 It is also worth considering the contribution that light intensity activity makes to overall daily energy expenditure. Findings from the Australian Diabetes, Obesity and Lifestyle cross-sectional study (AusDiab) reported by Dunstan et al. (2010) show that Australian adults spend up to 60% of their non-sleeping time being sedentary, with 35% of time spent on light-intensity (incidental movement) and usually less than 5% on moderate to vigorous physical activity. Some authors argue that light intensity activity can have potential health benefits; Healy et al. (2008) report that, 'light intensity activity has an inverse relationship with a number of cardio-metabolic markers'.

4.13 Wilmot et al. (2012) argue that, at a population level, sedentary behaviour is not usually substituted with higher MVPA but with higher levels of light intensity activity. Several authors (Healy et al. 2008, Owen et al. 2010, Prince et al. 2014a) argue that promoting increases in light-intensity activity should feature as an additional element (but not a replacement for) increasing MVPA.

Risks of Sedentary Behaviour

4.14 In recent years epidemiological evidence, supported by physiological studies, has identified sedentary behaviour as a distinct health risk (Owen, 2011). The evidence suggests that prolonged sedentary time affects an enzyme involved in lipid metabolism which worsens the cholesterol balance in the blood.

4.15 Some studies suggest that a high level of sedentary behaviour is related to risk for type 2 diabetes, cardiovascular disease, breast and colon cancer and poor mental health outcomes (Veerman 2012, Owen 2010 & Tremblay 2010). In addition, 'unhealthy' eating behaviours are also often associated with sedentary activities, such as watching television, going to the cinema, reading etc., which may increase the risk of weight gain (Martinez-Ramos et al., 2015).

4.16 Prince et al., (2014a) in a systematic review and meta-analysis of controlled trials report that there is also a gradient effect, whereby the risks for morbidity and mortality are higher in those people engaging in higher amounts of sedentary behaviour. They argue that these risks are independent of regular moderate-to-vigorous physical activity (MVPA).

4.17 Owen (2011) describes the distinction between standing and sitting; standing may not have the same negative metabolic effects as sitting, as standing enlarges the large muscles of the lower body, however, standing would also be classed towards the lower end of energy expenditure.

4.18 It is not just total sedentary time which is important, but also the pattern in which it is accumulated. In a smaller cohort of the AusDiab study (n=168), Healy et al. (2008) found that regular breaks in sedentary time (distinct from overall volume of sedentary time) were beneficial. Independent of total sedentary time, MVPA time and mean intensity of activity, having a higher number of breaks was beneficially associated with waist circumference, body mass index, triglycerides, and 2-hour plasma glucose.

The Extent of Sedentary Behaviour

4.19 According to Public Health England (2014), 'more than 40% of women and 35% of men spend more than six hours a day desk-bound or sitting still'. These self-report data are from the 2012 Health Survey for England.

4.20 The report also showed that sedentary behaviours in people surveyed increased at the weekend compared with a week day; on average, men spent 4.9 hours and women 4.7 hours being sedentary on week days, whereas on weekend days this rose to 5.4 hours and 5.1 hours, respectively.

4.21 The British Heart Foundation report 'Physical Activity Statistics 2015' (Townsend, 2015) presents information from the Health Survey for England 2012 broken down by age range. The survey in 2012 comprised 8,291 adults who provided self-reported data.

4.22 Figures 3 and 4 present this information across life stages and demonstrate that the highest levels of sedentary behaviour are seen in those aged 16-24 years and aged 65 and over, during both weekdays and weekends. Generally, across all age groups, the amount of sedentary time spent increases during the weekend.

Figure 3 - Adults reporting 6 hours or more sedentary time on <u>weekdays</u> by age and gender, England 2012 (Health Survey for England, 2012)

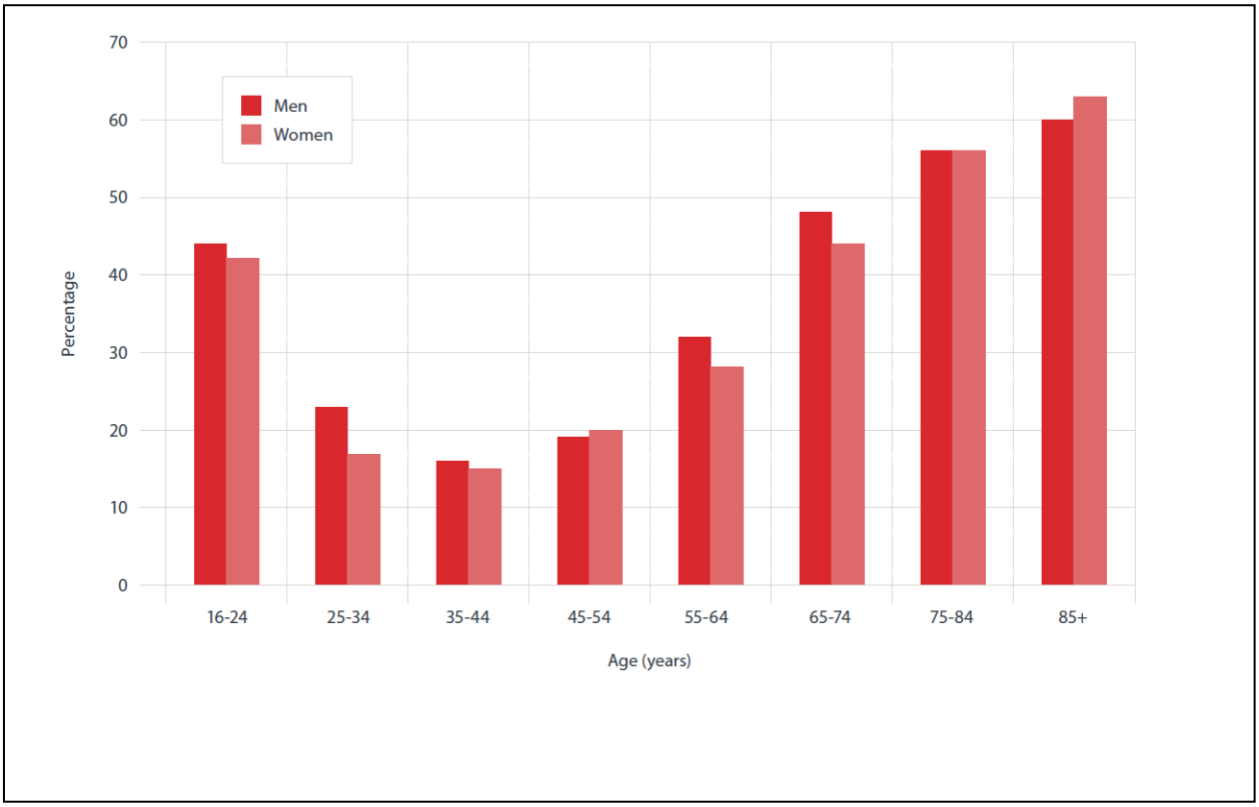
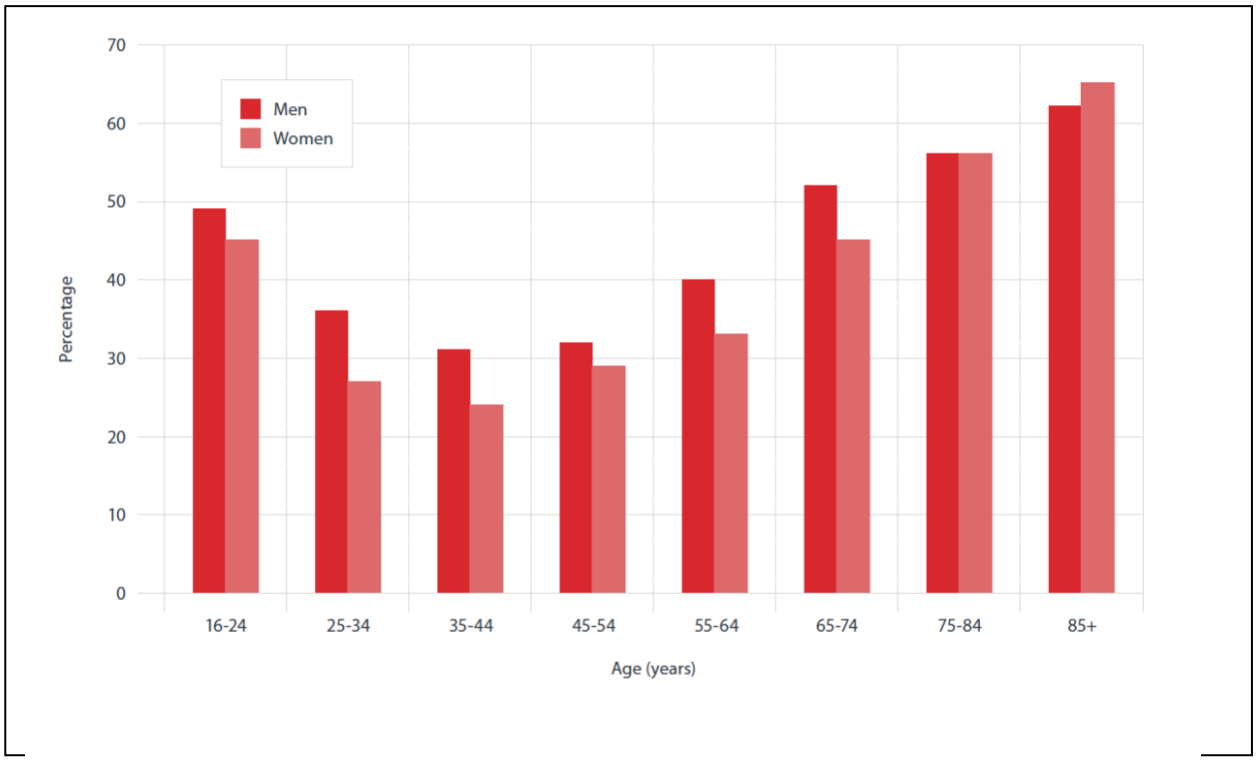


Figure 4 - Adults reporting 6 hours or more sedentary time on <u>weekends</u> by age and gender, England 2012 (Health Survey for England, 2012)



4.23 The survey responses include all sedentary time during the day, including occupational and leisure sedentary time. The lowest prevalence of sedentary time for both weekdays and weekends is in the 35-44 age group.

Types of Sedentary Behaviour

4.24 Published literature tends to categorise sets of sedentary behaviours according to the setting in which they occur. According to Owen et al. (2011) these settings are commonly:

- Leisure & household setting - this includes TV viewing, using a computer and other recreational screen time (tablets etc.)
- Occupational setting - predominantly prolonged workplace sitting (at desks and computers)
- Transportation setting - prolonged sitting in cars during travel

4.25 The Physical Activity Statistics Report (Townsend, 2015) gives some insight into the types of sedentary activities carried out in adults' leisure time. For almost all age groups, the highest proportion was spent watching television, in all age groups this was over 50% of total sedentary time. Other sedentary behaviours included sitting down for activities such as reading, doing homework, drawing, using a computer or playing video games.

4.26 Studies targeting sedentary behaviour in the workplace are much more numerous, therefore a focus on leisure sedentary behaviour is felt to be more useful, particularly given that adults are generally more sedentary during the weekend, when most people will be spending their leisure time.

4.27 Prolonged sitting in cars is an important contributor to total sedentary time, as many households have lifestyles that revolve around the use of the car. Much evidence is available around promotion of active travel, cycling and walking, and the benefits this yields. Jarrett et al. (2012) suggest that switching to active travel for short motor vehicle trips could save £17bn in NHS costs over 20 years. The largest savings would come through a reduction in cases of type 2 diabetes (£9bn). Discussion regarding active travel, car use and sedentary behaviour is outside the scope of this review.

5. Influences on Sedentary Behaviour

An Ecological Model

5.1 In order to develop evidence-based public health strategies and interventions to impact on population wide levels of sedentary behaviour, there is a need to understand the influences on these behaviours in different behavioural settings (Tremblay et al. 2010).

5.2 The ecological model developed by Owen et al. (2011) at Figure 5 describes multiple levels of influence on sedentary behaviour, including individual, social, organisational / community, environmental and policy.

5.3 The model takes a behavioural settings approach and describes sedentary behaviour in the context of four domains; leisure time, transport, household and occupation. For example, TV viewing and recreational screen time (sedentary behaviours) most commonly occur in the domestic and leisure domain.

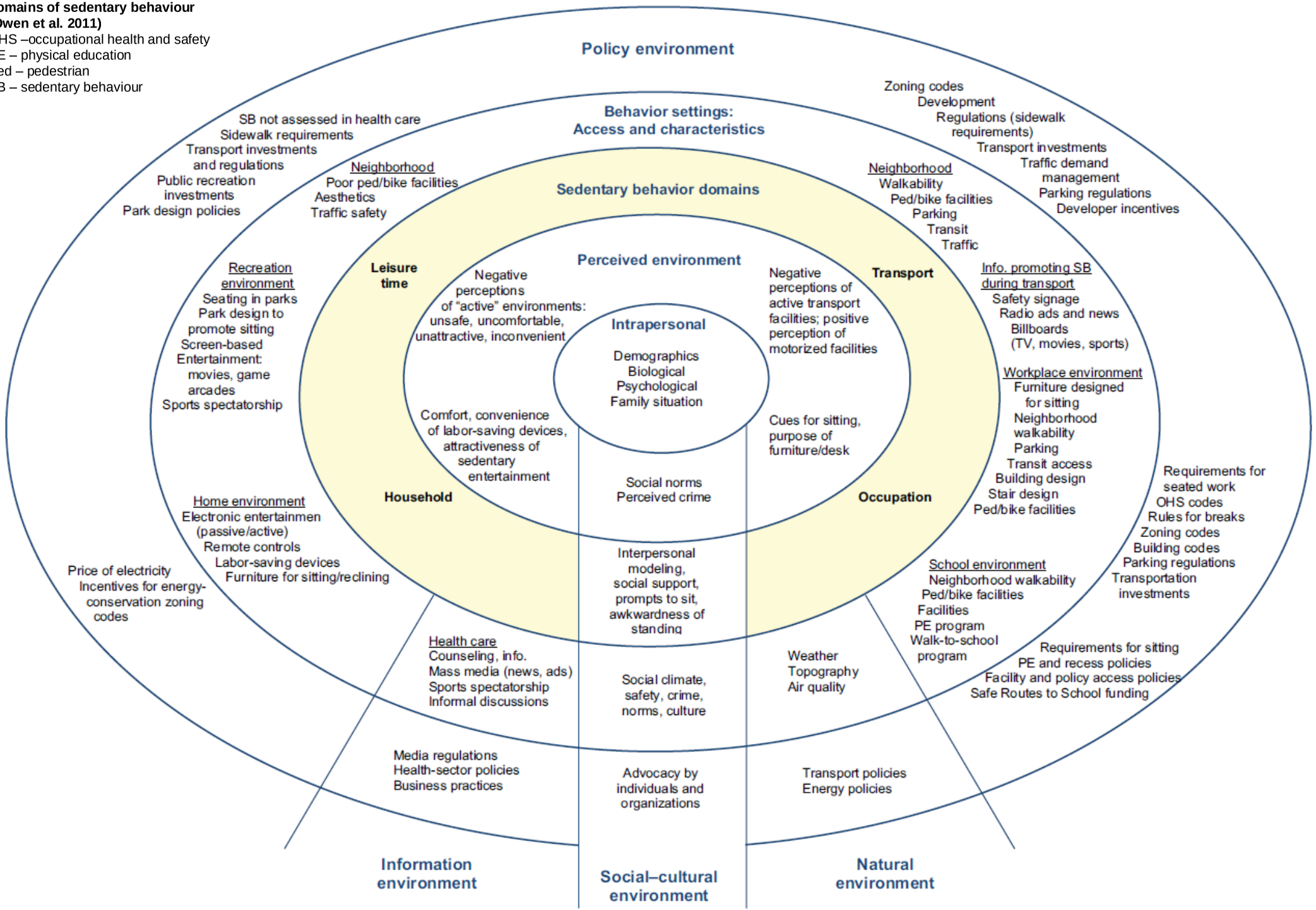
5.4 The social-cultural environment has strong influences on sedentary behaviour; individuals' motivations and preferences, family and social circumstances, the normative climate of their community and social networks (as well as the material resources) will all be important elements affecting behavioural choices. For example, there is a strong social norm to sit in meetings, in classes, at the theatre or at home relaxing. These norms are facilitated by environmental prompts, such as providing chairs and by prohibiting standing in class or in the theatre.

5.5 Social norms can also act as a barrier to reducing sedentary behaviour. For example, negative views of 'active' environments may lead to them being perceived as unsafe, uncomfortable or inconvenient.

5.6 Sedentary behaviour can also be strongly influenced by environmental attributes. In the above example, one could argue that 'prolonged sitting has been engineered into our lives', (Dunstan, 2010); living rooms are often configured and designed around the TV screen as a focus of the room.

5.7 The ecological model demonstrates the complex influences on sedentary behaviour, with a broad range of factors working at different levels. Owen et al. (2011) argue that future research needs to focus on the most important modifiable behavioural determinants; in order that interventions can be tailored to a specific behaviour, specific setting and specific population group.

Figure 5 – Ecological model of domains of sedentary behaviour (Owen et al. 2011)
OHS –occupational health and safety
PE – physical education
Ped – pedestrian
SB – sedentary behaviour



6. Changing Sedentary Behaviour – Strategies, Barriers and Facilitators

Behaviour Change Strategies

6.1 To develop effective sedentary behaviour change interventions, it is useful to explore the different strategies and techniques that are commonly used.

6.2 Gardner et al. (2015) undertook a review of 38 interventions to reduce sedentary behaviour in adults (12 of which were non-workplace studies) in order to explore the approaches associated with effective interventions.

6.3 Each intervention was coded according to a 'function' description and a 'behaviour change technique' description (described below), using the Behaviour Change Wheel and Behaviour Change Taxonomy model (Michie et al., 2011).

Function Descriptions

- Education – increasing knowledge or understanding
- Persuasion – using communication to induce positive or negative feelings or stimulate action
- Incentivisation – creating expectation of reward
- Coercion – creating expectation of punishment or cost
- Training – imparting skills
- Restriction – using rules to reduce the opportunity to engage in the target behaviour/or to increase the target behaviour by reducing the opportunity to engage in competing behaviours
- Environmental restructuring – changing the physical or social context
- Modelling – providing an example for people to aspire to or imitate
- Enablement – increasing means/reducing barriers to increase capability or opportunity beyond environmental restructuring

Behaviour Change Techniques

6.4 The Behaviour Change Taxonomy Model uses a 93-item coding frame to describe techniques present in an intervention (Michie et al. 2011). The model allows a researcher to be specific around the mechanisms of an intervention.

6.5 Descriptive analyses and statistical tests were undertaken, however, as the focus was to assess potential according to intervention function and characteristics, the authors state that meta-analysis of results was not appropriate. Instead, interventions were categorised according to how 'promising' their outcome data were.

6.6 Out of 38 interventions, 15 were categorised as 'very promising', eight 'quite promising' and 15 'non-promising', as described below:

- 'very promising' – significant reductions in at least one sedentary behaviour indicator in the intervention group and this reduction was greater than at least one comparator arm

- 'Quite promising' – where there were **either** significant declines in at least one sedentary behaviour indicator in the intervention group **or**

reduction in at least one sedentary behaviour indicator was greater than observed in a comparator arm

- 'Non-promising' – where there were **neither** sedentary behaviour changes in the intervention group **nor** differences in sedentary change relative to a comparator arm

6.7 Those interventions which showed most 'promise' were those using the function of **education, environmental restructuring, persuasion and training**. In terms of techniques, those most closely associated with promising interventions were **self-monitoring of behaviour, problem solving, modifying the social or physical environment and giving information on the health impact of sitting**.

6.8 Most promising interventions were those primarily aiming to change sedentary behaviour, rather than physical activity. Several physical activity interventions reported changes in activity, but not sedentary behaviour.

6.9 This type of analysis does not provide definitive conclusions regarding the most effective intervention components, as the analysis was based on non-standardised outcomes and was not part of a meta-analysis. However, it does highlight which behaviour change strategies have shown promise in previous studies.

Barriers and Facilitators

6.10 Reducing sedentary behaviour requires interventions that are feasible, practical, acceptable and effective. An important aspect of this is to understand the motivations, beliefs, preferences and opinions of the target audience. Much literature contends that it is unlikely that adults are very conscious of the problems associated with high levels of sedentary behaviour or its consequences (Martinez-Ramos et al. (2015), Rhodes et al. (2012)). Understanding and acting on insight from the target population is particularly important in order to illicit motivation to change.

6.11 Martinez-Ramos et al. (2015) carried out a small descriptive-interpretive qualitative study to explore opinions of primary-care patients (overweight or obese) around willingness to change behaviour, barriers, facilitators, goals and expectations. The study involved three healthcare centres in Barcelona with 23 patients (aged 25-65 years). Data were collected through conversational methods in group sessions, semi-structured interviews, triangle groups and a focus group. The main findings of the study were:

- Participants had a lack of awareness of time spent sitting and did not know about the negative health consequences over the long term. They viewed sedentary behaviour as 'normal' and, although there was some interest in reducing it, difficulties in achieving this were envisaged. For change to be possible, participants expressed a need for attractive alternatives that they would enjoy.

- The most usual activities carried out whilst sitting were working and sitting in front of a computer. At home, watching TV and using the computer were mentioned most. Most journeys were made by car or by public transport rather than walking.

- Difficulties in changing this behaviour related to family and work routines and lack of time. Socio-cultural barriers were mentioned along with lack of willpower, tiredness and the difficulty in being more active with increasing age.

- Factors suggested that would decrease sedentary behaviour included feeling emotionally and physically better after being active, a supportive environment of family and friends who are more active, more free time and good weather to encourage time spent outdoors.

- Participants expressed a need for change to happen at a social level using information campaigns, also within a corporate culture setting.

- In terms of support within a primary care setting (within which this study was based) participants suggested offering group interventions, 1:1 appointments and follow-ups with patients to support behaviour change.

6.12 This small study provides a sample of opinions of a small group of participants (n=23), however there are limitations; patients who participated could have been more aware of the risks of prolonged sitting time and therefore had stronger feelings about changing habits. In addition, the sample selected were aged 25-65, predominantly female and overweight/obese therefore their opinions may not be applicable to other segments of the population.

7. Factors Associated with Sedentary Behaviour

7.1 A systematic review carried out by Rhodes et al. (2012) explored 109 papers to appraise and theme potential associations with sedentary behaviour (in adults). There is a lack of evidence describing the determinants of sedentary behaviour, however the authors state there are a number of socio-demographic and health factors which 'seem reliably linked to sedentary behaviour' (Rhodes et al. 2012). A summary of results is presented overleaf in Figure 6.

Figure 6 - Summary of potential correlates of sedentary behaviour (Rhodes et al. 2012)

Factor	Sedentary Behaviour	No. of studies	Association
Age	TV viewing	20	+
	Screen viewing	3	?
	Computer use	5	-
	Reading	3	0
	General sitting	10	?
Education	TV viewing	18	-
	Computer use	4	+
	General sitting	6	0
Employment Status			
Unemployed/retired	TV viewing	15	+
	Computer use	4	?
	Sitting	7	?
Manual labour	Sitting	4	?
Increased occupational physical activity	TV/screen viewing	4	0
Gender (male)	TV viewing	29	0
	Computer use	9	?
	Video games	4	+
	Screen viewing	6	0
	Reading	4	0
	General sitting	9	0
BMI	TV viewing	28	+
	Computer use	4	?
Ethnicity	TV viewing	13	?
	General sitting	3	0
Marital Status	TV viewing	9	?
Income	TV viewing	14	?
	Computer use	3	0
Children in home	General sitting	4	-
Smoking	TV viewing	9	?
	General sitting	5	0
Alcohol consumption	TV viewing	8	0
	General sitting	4	0
Leisure time physical activity	TV viewing	25	-
	Computer use	3	0
	Screen viewing	6	-
	General sitting	9	0
Caloric intake	TV viewing	10	0
	General sitting	3	0
Sedentary attitude	TV viewing	3	+
	Computer use	3	+
Depressive symptoms	TV viewing	4	+
	Computer use	3	0
Life satisfaction	TV viewing	7	-

Note: at least 3 studies were required for a theme and an estimate of each sedentary behaviour.

+ positive association (>59% of studies) - negative association (>59% of studies)
? indeterminate association (34%-59% studies) 0 no association (<34% studies)

7.2 One of the most prevalent behaviours measured by the studies included was TV viewing and, as a result, this behaviour featured more frequently in the positive associations; linked with age, unemployed/retired, BMI, sedentary attitude and depressive symptoms. The other positive associations found were video gaming with gender (male), computer use with a sedentary attitude and computer use with level of education. It is important to note that these factors are just associations with sedentary behaviour and do not indicate causal relationships.

7.3 An interesting finding from this review is that there are differences in associations by type of sedentary activity measured. For example, TV viewing and computer use had similar associations however they were in the opposite direction (i.e. education and age). This supports the notion that sedentary behaviours are highly specific and the research domain is complex. Wilmot et al. (2012) argue that TV viewing may actually be a poor measure of overall sedentary time, which may lead to under-reporting, and advocates further research on measuring other forms of sedentary behaviour.

7.4 It is difficult to make definitive conclusions from the analysis as the authors state that there are some limitations; some studies proposed positive correlations but the effect sizes were small, there was a lack of any standardised measure of behaviour which makes comparisons challenging, most studies were cross-sectional and some of the studies relied on self-report measures which may be subject to bias.

8. Interventions to Influence Sedentary Behaviour

8.1 Two systematic reviews of interventions were found which used meta-analysis techniques (Martin et al. (2015) and Prince et al. (2014a)). These reviews are published recently and give a comprehensive overview, a summary of which is shown in Figure 7 (page 20).

8.2 For some interventions the two systematic reviews came to different conclusions, which may be due to different classification systems; Martin et al. (2015) classed some interventions as 'lifestyle' whereas Prince et al. (2014a) classed some of the same interventions as 'physical activity'. This had an evident effect on their overall conclusions.

8.3 A number of studies included self-reported measures to report on outcome effects. Prince et al. (2014a) argue that self-reported sedentary time can have low to moderate correlation with accelerometer-derived sedentary time. The authors recommend the use of inclinometers in future research, which are able to capture differences in body position (e.g. sitting vs. lying vs. standing), leading to a fuller understanding of patterns of sedentary behaviours.

8.4 The interventions reviewed fell into four category types:

- Physical activity
- Physical activity and sedentary behaviour
- Lifestyle (including multi-component aspects e.g. diet)
- Sedentary behaviour

8.5 Further papers were found relating to smartphone technology tackling sedentary behaviour; through interrupting behaviours, delivery of motivating messages, a real-time feedback loop and ability to reach across all environments. These studies are discussed separately in section 8.22.

8.6 Interventions which were carried out in a workplace setting have not been included in this report as are outside the scope of the research questions.

Systematic Review Details

8.7 **Martin et al. (2015)** searched 13 databases, trial registers and reference lists. Interventions were categorised as PA (physical activity) only, PA and SB (sedentary behaviour), lifestyle interventions (PA/SB and diet) or SB only. Fifty-one studies were included (18,480 participants aged 16-60 years), 44 were RCTs and seven were cluster RCTs conducted in Europe, USA, Australia and China. Twenty-three studies were with overweight or obese adults, five studies with type 2 diabetics and three studies with high level cardiovascular risk patients. Two studies were conducted with pregnant women. 36 of these studies were included in the meta-analysis. Full details of the studies can be found at: http://bjsm.bmj.com/content/suppl/2015/04/23/bjsports-2014-94524.DC1.html

8.8 Effect sizes were estimated as mean differences between the intervention and control groups in minutes per day (min/day) and studies were included with any of the following outcomes:

- Objectively measured SB obtained from accelerometers
- Objectively measured sitting time obtained from inclinometers
- Objectively or self-reported patterns of accumulation of SB
- Self-reported sitting time
- Self-reported proxy measures of sitting time where it was not certain that participants were sitting (e.g. screen time, transport time) and proxy measures of overall SB (e.g. occupational sitting time)

8.9 **Summary**: overall, this review reported a beneficial effect of interventions specifically targeting the reduction of sedentary behaviour as well as interventions adopting a lifestyle approach. The authors concluded that there was no evidence of a statistically significant effect of PA interventions or combined PA/SB interventions for reducing SB. This is in contrast with the findings (below) from the Prince et al. (2014a) systematic review, which may be due to the differences in classification of studies as outlined in 8.2.

8.10 **Prince et al. (2014a)** searched six databases to identify studies targeting PA and/or SB and reporting changes in SBs (sedentary, sitting or TV viewing time). Sixty-three studies were included, with 25,446 participants aged 18 to 94 years. Studies were conducted in 18 countries with the majority from the United States, Australia and the UK. Nine studies used non-RCT designs, whilst the remaining used a RCT design. Thirty-three of these studies were included in the meta-analysis, details of which can be found at: http://dx.doi.org/10.1111/obr.12215

8.11 The primary outcome measure was the mean difference or changes in SB (e.g. sedentary time, sitting time, TV viewing) in minutes per day (min/day) following exposure to the intervention.

8.12 **Summary**: overall this review concluded that there is evidence of a beneficial effect of interventions solely targeting SB. The authors argue that interventions with a focus on PA or those including both a PA and SB elements were of lower quality, produced less consistent findings and generally resulted in only small and modest reductions in sedentary time.

Figure 7 – Overall results of systematic reviews

Martin et al. (2015)				
Intervention type	**Physical Activity**	**Physical Activity + Sedentary Behaviour**	**Lifestyle (multi-component with nutritional element)**	**Sedentary Behaviour**
Number of studies	(9)	(3)	(20)	(2)
Setting	7 - community/home 2 - workplace	2 – community/home 1 – workplace	15 – community/home 3 – GP/hospital 2 - workplace	2 - workplace
Meta-analysis results	'no evidence of statistically significant effect on sedentary behaviour'	'no evidence of statistically significant effect on sedentary behaviour'	'statistically significant reduction in sedentary behaviour'	'statistically significant reduction in sedentary behaviour'
Quality of studies	Moderate	Moderate	Moderate to high	Low
Pooled results (mean difference in min/day, 95% CI)	-8.34 [-36.02, 19.34]	-34.55 [-173.93, 104.83]	-24.18 [-40.66, -7.70]	-41.76 [-78.92, -4.60]

Prince et al. (2014a)				
Intervention type	**Physical Activity**	**Physical Activity + Sedentary Behaviour**	**Lifestyle (multi-component with nutritional element)**	**Sedentary Behaviour**
Number of studies	(22) *	(6)	-	(7)
Setting	14 – community/home 7 – GP/hospital 1 - workplace	3 – community/home 1 – GP 2 - workplace	-	1 – home 6 - workplace
Meta-analysis results	'less consistent findings' 'modest reductions in daily sedentary time'	'less consistent findings' 'modest reductions in daily sedentary time'	*This classification not used*	'significant and large reduction in sedentary daily time'
Quality of studies	Moderate	Moderate	-	Moderate
Pooled results (standardised mean difference in min/day, 95% CI)	-0.22 [-0.35, -0.10] Equating to $^{+}$MD of 19 min/day less ST in intervention group	-0.37 [-0.69, -0.05] equating to $^{+}$MD of 35 min/day less ST in intervention group	-	-1.28 [-1.68, -0.87] Equating to $^{+}$MD of 91 min/day less ST** in intervention group

* Prince et al. included lifestyle interventions within their 'Physical Activity' category (Martin et al. had a separate classification for 'Lifestyle' interventions) which includes multi-component interventions some with a nutrition element.
** ST = sedentary time
$^{+}$MD = mean difference

Physical Activity Interventions

8.13 As detailed in Figure 7, Martin et al. (2015) reported a mean difference of -8.34 minutes per day (of sitting time) following physical activity interventions, (95% CI: -36.02 to 19.34, p=0.55) but this was not a statistically significant effect. In contrast, Prince et al. (2014a) found small but statistically significant reductions in sedentary time; a mean difference of approximately -19 minutes per day following the intervention (95% CI: -0.35 to -0.11, p =<0.0005).

8.14 A small number of studies showed a beneficial effect in terms of reducing sedentary behaviour, detailed in Appendix 2. It is important to bear in mind that, as the number of studies is small and based on low numbers of participants it is difficult to draw firm conclusions about the power of the effect. Indeed, some studies did not show a reduction in sedentary time, which adds weight to the argument previously discussed; that one cannot assume that an increase in physical activity will automatically lead to a decrease in sedentary behaviour.

Physical Activity and Sedentary Behaviour Interventions

8.15 In these dual aim interventions, the two systematic review results again differ. Martin et al. (2015) report that the combined PA and SB interventions they reviewed did not produce any statistically significant effect. Prince et al. (2014a) conclude that interventions which either jointly focused on or included PA and SB components *may* result in modest reductions of sedentary time. Prince et al. (2014a) reviewed six studies in this category compared to three by Martin et al. (2015). Two studies showed results that were statistically significant, one of which was included in both systematic reviews, described in Appendix 3.

8.16 The systematic reviews report that the quality of the studies is moderate, which may be partly due to the heterogeneity and small number of studies. Again, it is difficult to draw firm conclusions with systematic reviews that point to different findings, therefore, there is very limited evidence that combined physical activity and sedentary behaviour interventions can have a statistically significant effect on reducing sedentary time.

Lifestyle Interventions

8.17 Due to classification differences, as previously discussed, the Martin et al. (2015) systematic review is the only one in this report which includes 'lifestyle interventions' as a study category. These study designs are reported favourably, with the combined meta-analysis results reducing SB by 24 min/day (95% CI: -40.66, -7.70 min/day). The authors graded the quality of studies in this category (20 studies) as moderate and suggest that this may be a promising approach.

8.18 Further high quality studies are needed, however, to explore the potential for reducing sedentary behaviour in a sustainable way as part of a holistic approach to promoting healthy lifestyles. A sample of the studies which reported favourable reductions in sedentary behaviour are shown at Appendix 4.

Sedentary Behaviour Interventions

8.19 There are far fewer studies with sedentary behaviour reduction as the primary outcome, reflecting this relatively newer research focus. Martin et al.'s (2015) systematic review included only two interventions and Prince et al.'s (2014a) systematic review included six. In both the meta-analyses, these type of interventions (work and home settings) had the most significant effects.

8.20 It is important to note that out of the eight studies, only one of them was undertaken in a leisure/home setting (described in Appendix 5), with the rest of the studies delivered in workplace settings.

8.21 Tackling behaviour change within a home/domestic setting is potentially more challenging than a workplace setting, where one could argue a large captive audience is available to receive an intervention. Further high quality studies are needed to determine if sedentary behaviour interventions are to produce meaningful reductions in sedentary leisure-time.

Smart-phone Technology-based Interventions

8.22 According to Ofcom (2015) two-thirds of adults in the UK now have a smartphone. Improvements in technology, availability and affordability have made it easier for people to go online whenever they wish.

8.23 Younger age groups are the most likely to own a smartphone: 90% of 16-24 year olds and 87% of 25-34 year olds claim to have one. Older people are less likely to have a smartphone, however, the most substantial increase in ownership in the past three years has been in adults aged 55-64 (19% in 2012 to 50% in 2015). Amongst adults aged over 65, ownership has increased from 5% in 2012 to 18% in 2015 (Ofcom, 2015).

8.24 Mobile technology can reach a large proportion of the population in a timely and cost-effective manner to intervene and break up behaviours, deliver motivating messages and support through a real-time feedback loop. Smartphone technology is already used across healthcare settings, for example in decision making processes in clinical practice of which there is some evidence of their usefulness (Recio-Rodriguez, 2014). Short message service (SMS) communication has also demonstrated some effectiveness in helping people to give up smoking (Free et al. 2011).

8.25 In recent years there has been huge increase in the number of lifestyle applications (apps) available for smart phone technology. King et al. (2013) estimate that the number might run into the thousands, but argue that relatively few of them are underpinned by relevant behaviour change theory or evidence, or have undergone systematic evaluation.

8.26 Free et al. (2013) carried out a systematic review of 75 mobile phone technology interventions, 26 of which related to behaviour change trials including smoking cessation, increased physical activity and calorie reduction. The authors concluded that there was mixed evidence regarding the benefits of the interventions. Only three interventions included secondary outcomes relating to sedentary behaviour (summarised in Appendix 6) however none of them produced statistically significant reductions in sedentary behaviour.

8.27 Outside of this systematic review, three further non-RCT studies were found relating to smartphones (published in the last three years). Advances in technology, such as built-in accelerometers, means that devices can provide

objective monitoring and be programmed to provide automated and tailored information to users. These studies (described in Appendix 7) are very small scale and have not been part of a systematic review, so it is difficult to judge the quality of their design. However, they do offer some interesting insight into providing cost-efficient ways to prompt behaviour change and interrupt sedentary behaviour across wide sections of the population.

8.28 Bond et al. (2014) argue that sitting, unlike exercising, is highly habitual and carried out without any conscious effort for many hours. Interventions to break up this behaviour need to be simple, require minimal forethought and planning, and easily implemented in many environments. Smartphone technology may provide a way to do this however further research is needed. There is a dearth of evidence of longer term follow up of participants and there is a need to explore the sustainability of this approach, given that there may be a high attrition rate from mobile phone apps as users' interest diminishes.

9. Conclusions

Conclusions from the Literature

9.1 This review has explored some of the latest research on sedentary behaviour as well as interventions designed to reduce it. Very often this aim is not the primary outcome of studies, and systematic reviews confirm that when a reduction in sedentary behaviour is not the prime focus, the results are less effective.

9.2 Interventions which target an increase in physical activity may not necessarily automatically lead to a reduction in sedentary time in participants, as this is a distinct behaviour in its own right with numerous determinants in different settings.

9.3 The literature suggests that high levels of prolonged sedentary time, **independent** of the time spent in moderate or vigorous intensity physical activity, is associated with health risks including type 2 diabetes, cardiovascular disease, metabolic syndrome and obesity. Even when an individual meets the CMO recommendations for physical activity, they may still spend long periods of time being sedentary.

9.4 As well as the importance of reducing total sedentary time, weight must be given to the need to frequently interrupt prolonged sitting time. In a smaller cohort of the Australian Diabetes, Obesity and Lifestyle cross-sectional study (AusDiab) (n=168), Healy et al. (2008) found that regular breaks in sedentary time (distinct from overall volume of sedentary time) were beneficial. Independent of total sedentary time, MVPA time and mean intensity of activity, having a higher number of breaks was beneficially associated with waist circumference, body mass index, triglycerides, and 2-hour plasma glucose.

9.5 The ecological model (page 13) highlights how important it is that sedentary behaviour is understood at a 'systems level'. This model describes multiple levels of influence on sedentary behaviour, including individual, social, organisational / community environmental and policy. It is therefore important to champion and advocate for environmental, transport and planning policy that can create environments to facilitate behaviour change such as being less sedentary.

9.6 According to Public Health England (2014), 'more than 40% of women and 35% of men spend more than six hours a day desk-bound or sitting still'. The highest levels of sedentary behaviour are seen in those aged 16-24 years and aged 65 and over. Generally, across all age groups, the amount of sedentary time spent increases during the weekend.

9.7 Much literature contends that it is unlikely that adults are very conscious of the problems associated with high levels of sedentary behaviour or its consequences.

9.8 Some difficulties individuals cite as acting as a barrier to reducing sedentary behaviour relate to family and work routines and lack of time. Socio-cultural barriers are also mentioned; being sedentary is viewed as 'normal', as well as lack of willpower, tiredness and the difficulty in being more active with increasing age.

9.9 For those people who are not regularly active, a focus on reducing sedentary behaviour and increasing light intensity activity may be a more achievable goal for increasing movement and energy expenditure, as a first step along the way to being more active. Light intensity activity contributes to daily energy expenditure and has potential health benefits; Healy et al. (2008) report that, 'light intensity activity has an inverse relationship with a number of cardio-metabolic markers'.

9.10 Interventions with a primary focus on reducing sedentary behaviour may be more effective than interventions which focus on increasing physical activity or lifestyle change, however further high quality studies are needed to determine whether clinically meaningful and sustainable reductions in sedentary leisure time are possible; this was not addressed by the systematic reviews. Many sedentary behaviour interventions are set within the context of workplaces so further high quality research is needed based within a leisure setting where the determinants of behaviour will be different.

9.11 A number of studies published include self-reported measures to determine intervention effect. Prince et al. (2014a) argue that self-reported sedentary time can have low to moderate correlation with accelerometer-derived sedentary time. While accelerometers can objectively measure movement, they cannot record context and Prince et al. (2014a) argue only have moderate ability to detect sitting time. These authors recommend the use of inclinometers in future research, which are able to capture differences in body position (e.g. sitting vs. lying vs. standing), leading to a fuller understanding of patterns of sedentary behaviours.

9.12 According to Ofcom (2015) two-thirds of adults in the UK now have a smartphone, with 90% of 16-24 year olds and 87% of 25-34 year olds claiming to own one. Interestingly, as well as having the highest level of ownership of smartphones,16-24 year olds are also the most sedentary when looking at adults under 65 (Health Survey for England 2012).

9.13 The number of apps available around behaviour change has exploded in recent years. This technology offers the potential to reach a large proportion of the population in a timely and cost-effective manner. Some of the smartphone interventions reviewed in this report may offer some promise in providing potentially cost-efficient ways to prompt behaviour change such as interrupting sedentary behaviour. However there is a need for research to explore the sustainability of this type of approach, along with studies being systematically reviewed and evaluated.

10. Recommendations and Implications

10.1 As a result of this literature review, a number of recommendations are made:

10.2 It is important to raise awareness in the population of the importance of reducing and interrupting sedentary behaviours *alongside* the benefits of being physically active as part of any physical activity or lifestyle intervention. Strategy and policy makers should not assume that the solution to reducing sedentary behaviour is to solely promote increased levels of physical activity.

10.3 Consideration needs to be given to how this intelligence is shared with commissioners and providers in order that sedentary behaviour is acknowledged as a public health issue in its own right.

10.4 Tackling reduction of sedentary behaviours needs to take a systems-wide approach; not solely focusing on individual change but targeting the policies and strategies that create the physical and social environments within which we live and work. Relationships need to be built with stakeholders to share understanding about sedentary behaviour and advocate for embedding this broader approach to physical activity.

10.5 Findings from this review could be used to inform social norming programmes, designed to promote and normalise more active behaviours as part of an individual's everyday lifestyle.

10.6 Future programmes of work should identify the four domains of sedentary behaviour; leisure, transport, household and occupation. Mapping of stakeholders and activity within each of these domains would enable better understanding of the breadth of current work.

10.7 Findings from this review should inform work to increase physical activity levels within the population, acknowledging the important contribution that general everyday activity and reduction and interruption of sedentary behaviour can have on health; whilst recognising that they are separate entities and behaviours.

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11. References

Abascal, M., (2008) 'The effect of depression and adherence in a dietary and physical activity intervention for overweight and obese adults', *Dissertation Abstract International: Section B: The Sciences and Engineering*, Vol. 69 (4-B):2614

Ainsworth, B., Haskell, W., Whitt, M. et al (2000), 'Compendium of physical activities: an update of activity codes and MET intensities', *Medicine and Science in Sports and Exercise*, Vol.32 (9) (suppl) pp498-504

Anderson, E., Burton, N.W., and Anderssen, S.A. (2012), 'Physical activity levels six months after a randomised controlled physical activity intervention for Pakistani immigrant men living in Norway', *International Journal of Behavioural Nutrition and Physical Activity'*, Vol 9 :47

Barwais, F., Cuddihy, T. and Tomson, L. (2013) 'Physical activity, sedentary behaviour and total wellness changes among sedentary adults: a 4 week randomised controlled trial', *Health and Quality of Life Outcomes*, Vol.11 (183)

Bond, D., Thomas, G., Raynor, H. et al. 92014), 'B-MOBILE – a smartphone-based intervention to reduce sedentary time in overweight/obese individuals: a within-subjects experimental trial', *Plos One,* Vol. 9 (6), [Available online http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0100821]

British Heart Foundation National Centre (BHFNC). 2012. *Sedentary Behaviour Evidence Briefing.* BHFNC for physical activity and health

Burke, L., Lee, A., Jancey, T. et al. (2013), 'Physical activity and nutrition behavioural outcomes of a home-based intervention program for seniors: a randomised controlled trial'*, International Journal of Behavioural Nutrition and Physical Activity*, Vol. 10 (14)

Chang, A., Fritshi, C. and Kim, M. 'Sedentary behaviour, physical activity and psychological health of Korean older adults with hypertension; effect of an empowerment intervention', *Research in Gerontological Nursing*, Vol. 6, No. 2, pp81-88

De Cocker, A., De Bourdeaudhuij IM., Brown W, and Cardon, G. (2008) 'The effect of a pedometer-based physical activity intervention on sitting time', *Preventative Medicine,* 47 pp179–181

De Greef, K., Deforche, B.,Tudor-Locke, C. et al (2010), 'A cognitive behavioural pedometer based group intervention on physical activity and sedentary behaviour in individuals with type II diabetes', *Health Education Research,* Vol.5: pp724-736

Department of Health, 2010, *Sedentary Behaviour and Obesity: Review of the current scientific evidence',* DH, London

Department of Health, (2011) *Physical Activity Guidelines for Adults aged 19-64; Factsheet 4.*
[Available on line:
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/213740/dh_128145.pdf]

Dunstan, D., Healy, G., Sugiyama, T. et al (2010), 'Too much sitting and metabolic risk – has modern technology caught up with us?' *European Endocrinology*, Vol.6 No1, pp19-23

Fardi, Z., Liberti, L., Shuval, K et al. (2008), 'Evaluating the impact of mobile telephone technology on type 2 diabetic patients' self-management: the NICHE pilot study', *Journal of Evaluation in Clinical Practice*', 14: pp465-469

Free, C., Knight, R., Robertson, S. et al. (2011), 'Smoking cessation support delivered via mobile phone text messaging (txt2stop): a single-blind, randomised trial', *Lancet*, 378(9785):49–55

Free, C., Phillips, G., Galli, L. et al. (2013), 'The effectiveness of mobile-health technology-based health behaviour change or disease management interventions for health care consumers: a systematic review', *PLOS Medicine,* Vol 10, Issue 1
[Available online http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3548655/]

Gardner, B., Smith, L., Lorencatto, F. et al. (2015) 'How to reduce sitting time? A review of behaviour change strategies used in sedentary behaviour reduction interventions among adults', *Health Psychology Review,* [Available on-line http://dx.doi.org/10.1080/17437199.2015.1082146]

Hamilton, M. T., Healy, G. N., Dunstan, D. W. et al. (2008) 'Too little exercise and too much sitting: Inactivity Physiology and the need for new recommendations on sedentary behaviour', *Current Cardiovascular Risk Reports,* 2 (4), pp292-298

Health and Social Care Information Centre (2013). *Health Survey for England* 2012. Volume 1: Chapter 2 – Physical activity in adults. Health and Social Care Information Centre: Leeds

Healy, G., Dunstan, D., Salmon, J. et al. (2008) 'Breaks in sedentary time: Beneficial associations with metabolic risk', *Diabetes Care*, 31(4), pp661–6

Hu, G., Tian, H., Zhang, F. et al. (2012), 'Tianjin Gestational Diabetes Mellitus Prevention Program: study design, methods, and 1-year interim report on the feasibility of lifestyle intervention program', *Diabetes Research and Clinical Practice,* 98(3):pp508-517

Jarrett, J., Woodcock, J., Griffiths, U., et al. (2012), 'Effects of increasing active travel in urban England and Wales on costs to the National Health Service', *The Lancet*, 379: 2198-2205

King, C., Hekler, E, Grieco, L. et al. (2013), 'Harnessing different motivational frames via mobile phones to promote daily physical activity and reduce sedentary behaviour in ageing adults', *Plos One,* Vol. 8 (4) , [Available online http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0062613]

Martin, A., Fitzsimons, C., Jepson, R., Saunders, H., Van der Ploeg, H., Teixeria, Mutrie, N. (2015) 'Interventions with potential to reduce sedentary time in adults: systematic review and meta-analysis', *British Journal of Sports Medicine*, Vol: 49, pp1056-1063

Martinez-Ramos, E., Martin-Borras, C., Trujillo, JM., et al (2015) 'Prolonged Sitting Time: barriers, facilitators and views on change among primary healthcare patients who are overweight or moderately obese', Research article, [Available online http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0125739]

Michie, S., Van Stralen, M. and West, r. (2011), 'The behaviour change wheel: a new method for characterising and designing behaviour change interventions' *Implementation Science*, 6, 42. Doi:10.1186/1748-5908-6-42

Mutrie, N., Doolin, O., Fitzsimons, C. et al. (2012), 'Increasing older adults' walking through primary care: results of a pilot randomised control trial', *Family Practice*, Vol. 29 pp633-642

Ofcom, (2015) *The Communications Market Report*, [Available online http://stakeholders.ofcom.org.uk/binaries/research/cmr/cmr15/CMR_UK_2015.pdf]

Otten, J., Jones, K., Littenberg, B. and Harvey-Berino, J. (2009) 'Effects of television viewing reduction on energy intake and expenditure in overweight and obese adults: a randomised controlled trial', *Archive of International Medicine',* Vol.169 pp2109-2115

Owen, N., Sugiyama, T., Eakin, E., Gardiner, P., Tremblay, M. and Sallis, J. F. (2011) 'Adults' Sedentary Behaviour; Determinants and Interventions', *American Journal of Preventive Medicine,* Vol. 41 (2) pp189-196

Owen, N., Healy, G. Matthews, C. et al. (2010) 'Too much sitting: the population health science of sedentary behaviour' *Exercise and Sports Science Review*, Vol. 38 pp105-113

Pellegrini, C., Hoffman, S., Elyse, R. et al. (2015), 'Acceptability of smartphone technology to interrupt sedentary time in adults with diabetes', *Translational Behavioural Medicine*', (5): pp307-314

Prince, S., Saunders, T., Gresty, K. and Reid, R (2014a) 'A comparison of the effectiveness of physical and sedentary interventions in reducing sedentary time in adults; a systematic review and meta-analysis of controlled trials', *Obesity Reviews*, 15, pp905-919

Prince, S., Gresty, M., Reed, J., Wright, E., Tremblay, M., and Reid, R. (2014b) 'Individual, social and physical environmental correlates of sedentary behaviours in adults: a systematic review protocol', *Systematic Reviews,* 3:120 doi:10.1186/2046-4053-3-120
[Available on line: http://systematicreviewsjournal.com/content/3/1/120]

Public Health England (2014) *Everybody Active Every Day; An evidence-based approach to physical activity,* PHE publications gateway number: 2014432

Pulsford, R. (2014) *Sedentary Behaviour and Health,* Thesis for the degree of Doctor of Philosophy in Sport and Health Sciences, University of Exeter

Recio-Rodríguez, J., Martín-Cantera, C., González-Viejo, N. et al. (2014), 'Effectiveness of a smartphone application for improving healthy lifestyles, a randomized clinical trial (EVIDENT II): study protocol', *BMC Public Health* 14:254 [Available on line: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4003852/pdf/1471-2458-14-254.pdf]

Rhodes, R., Mark, R. and Temmel, C. (2012), 'Adults sedentary behaviour; a systematic review', *American Journal of Preventive Medicine'* Vol:42 (3) pp3-28

Rutten, G., Savelberg, H., Biddle, S., Kremers, S. (2013) 'Interrupting long periods of sitting time; good STUFF', *International Journal of Behavioural Nutrition and Physical Activity',* Vol. 10 no.1

Shapiro, J., Bauer, S., Hamer, R. et al. (2008), 'Use of Text Messaging for Monitoring Sugar-Sweetened Beverages, Physical Activity, and Screen Time in Children: A Pilot Study', *Journal of Nutrition and Educational Behaviour*, 40(6): pp385–391

Spring, B., Schneider, K., McFadden, B et al. (2012) 'Multiple Behaviour Changes in Diet and Activity: A randomised controlled trial using mobile technology', *Archive of International Medicine'* 172 (10): pp789-796

Townsend, N., Wickramasinghe, K., Williams, P. et al. (2015), *Physical Activity Statistics 2015.* British Heart Foundation, London

Tremblay M.S., Colley RC, Saunders TJ, Healy GN, Owen N. 'Physiological and health implications of a sedentary lifestyle', *Applied Physiology Nutrition and Metabolism,* (2010) 12; 35 pp725-40

Tremblay M.S., Esliger, D., Tremplay, A. and Colley, R. 'Incidental movement, lifestyle-embedded activity and sleep: new frontiers in physical activity assessment', *Canadian Journal of Public Health,* Vol. 98 (Suppl 2): pp208-217

Turner-McGrievy, G., Campbell, M., Tate, D. et al. (2009), 'Pounds Off Digitally study: a randomised podcasting weight-loss intervention', *American Journal of Preventive Medicine'*, 37, pp 263-269

Veerman, J., Healy, G., Cobiac, L. et al. (2012) 'Television viewing time and reduced life expectancy', *British Journal of Sports Medicine*, Vol. 46 pp197-206

Wilmot, E. G, Edwardson C. L., Achana, F. A. et al. (2012), 'Sedentary time in adults and the association with diabetes, cardiovascular disease and death: systematic review and meta-analysis', *Diabetologia*, Vol 55 pp2895–2905

APPENDIX 1

Search Strategy Results

Databases searched include:

CINAHL
MEDLINE
Ingenta Connext
Ovid online (Embase, AMED)
Cochrane
NIHR Library
Pub Med
Ebsco
NICE Healthcare Databases

Terms	**Results (limited 2005 – 2015)**
Sedentary	1805
Sedentary behavio*	111
Reduc* AND 'sedentary behaviour'	269
Interrupt* AND 'sedentary behaviour'	5
Sedentary AND interventions	177
Reduc* AND 'screen-time'	22
'sedentary behaviour' AND 'low-income'	268
'sedentary behaviour' AND adults	1
'break up' AND 'sedentary behaviour'	2
'sedentary behaviour' OR 'sedentary habits'	1668
Sedentary AND digital	157
Sedentary AND 'smart phone technology'	11

APPENDIX 2

Sample of Physical Activity Interventions Showing Beneficial Effects in Reducing Sedentary Behaviour

Study	Pop'n	Design and duration	Description	Control	Attrition	Authors con-clusion	Limitations
Anderson et al. (2012) (2) Norway	All male I = 76 C = 86 Mean age: I = 35.7 C = 39.7	RCT 6 months Community Accelero-meters used	'PA and minority health'. Group exercise x2 pw, two group lectures, one individual counselling session, written material and a phone call	Waiting list: organised exercise (x1 pw for 4 months) one lecture and written material at end of intervention	I = 16% C = 35%	Decreased sedentary behaviour in favour of intervention group	High attrition rate Lack of blinding of participants to group allocation
Burke et al. (2013) (1 & 2) Australia	478 older adults of low to medium socio-economic status I = 248 C = 230	Two-arm RCT 6 months Home-based	'PA and Nutrition for Seniors' booklet promoting diet and PA goals. Resources - exercise chart, calendar, newsletter, resistance bands and pedometers. Telephone and emails from programme guides.	No treatment	I = 29% C = 13%	Decreased sedentary behaviour in favour of intervention group	Self-report measures, no accelero-meters used
De Cocker et al. (2008) (1) Belgium	I = 648 C = 592 (aged 25 to 75) F/U; I = 440 C = 426	Multi-strategy community-based intervention 12 months	"10,000 Steps Ghent" (Belgium) promoted across community; media campaign, pedometers, website, workplace projects, older people projects, info to health professionals, schools etc. Strategies at the individual, social and environmental level	592 people from a comparison community	I =32% C = 28%	At 12m, - 12 min /day total daily sitting time in intervention community, +18 min/day in comparison community	Self-report measures, no accelero-meters used
Mutrie et al. (2012) (1& 2) UK – Glasgow	41 participants aged ≥65 years I = 20 C = 19	RCT 12 weeks General practice	The intervention group received two 30-minute physical activity consultations, a pedometer, *activ*PAL monitor (monitoring posture) and a walking programme, designed to increase walking activity.	The control group continued as normal for 12 weeks and then received the intervention	I = 0% C = 10% at 1st F/U 19% at 2nd F/U	Decreased sedentary behaviour in favour of intervention group. Increase in daily steps maintained at 24w post intervention	Small sample size

(1) Included in Martin et al. (2015) systematic review
(2) Included in Prince et al. (2014a) systematic review

APPENDIX 3

Physical Activity and Sedentary Behaviour Interventions

Study	Pop'n	Design and duration	Description	Control	Attrition	Authors conclusion	Limitations
Chang et al. (2013) Korea (2)	Older Korean adults with hyper-tension I = 27 C = 21	Controlled trial 8-weeks	'Empowerment intervention' on sedentary behaviour, physical activity, and psychological health. Experimental group received intervention including lifestyle modification education, group discussion, social support and exercise training for 8 weeks	Control group received standard hyper-tension education	unknown	Decrease in sitting time in IG, increased physical activity, increased self-efficacy for physical activity, and increased perceived health	PA and sedentary behaviour self-reported Participants chose their preferred intervention, thus motivation may have affected the results
Barwais et al. (2013) Australia (1 & 2)	22 men and 11 women Mean age: 27 years ± 4.0 I = 18 C = 15	RCT 4-week Home-based Tri-axial accelero-meter	Personal activity monitor-based programme designed to reduce sedentary behaviour and increase daily physical activity levels. Summary of daily activity patterns provided to user including goal-setting, graphs and charts to aid self-monitoring.	Control group followed normal daily lifestyle routines	0%	Decreased sedentary time in intervention group	Small sample size Self-report measures also used

(1) Included in Martin et al. (2015) systematic review
(2) Included in Prince et al. (2014a) systematic review

APPENDIX 4

Lifestyle Interventions

Study	Pop'n	Design and duration	Description	Control	Attrition	Authors conclusion	Limitations
Abascal (2008a) USA (1)	I = 153 C = 155 Mean age: 43.9 ± 8y All males	RCT 12 months Home based	'iPace Men in Motion on-line intervention - pedometer, web-based activities; learning and applying new behavioural skills, diet and PA topics. Encouragement to log on weekly to report weight and progress on goals (at least 10,000 steps (5-7 d/wk) and participating in strength training twice a week).	Access to an alternate website containing general health information	I = 32%, C = 29%, Total = 30%	Decreased sedentary behaviour in favour of the intervention group	Self-report measures Internet access req. Baseline, 6m, 12m measures only
Abascal (2008b) USA (1)	I=140 C=146 Mean age: 41.2 ± 8.7y All females	RCT 12 months General practice /home	"iPace Women in Balance": web-based assessment, health behaviour counselling follow-up via web, phone and email interaction with a health counsellor. Target behaviours included increasing PA (30-60 minute goal), fruit and vegetable intake, fibre intake, and decreasing dietary fat.	Previously scheduled GP visits without health behaviour counselling and info on diet and PA recommend-ations	I= 32%, C = 25%, total = 29%	No significant intervention effects on sedentary behaviour	Self-report measures Participants could only take part if access to internet Baseline, 6m, 12m measures only
De Greef et al. (2010) Belgium (1)	I=21 C=20 Mean age: 61.3±6.9y Male and female Type II diabetics	RCT 12 weeks Community /home	Lifestyle intervention (dietary and PA) five cognitive-behavioural group sessions of 90 min. In addition participants received a pedometer, accelerometer and diary as motivational tools	One single-group education on the effects of PA on diabetes care	9.7% 12m 12.2%	Decreased sedentary behaviour in favour of the intervention group	Small sample Allocation not blinded SB increased to baseline levels in the longer term
Hu et al. (2012) China (1 & 2)	I=192 C=212 Mean age: I= 32.3 ±3.6y All females	RCT 12m + 12m mainten-ance home	A 2-week ''run-in'' period with 2 classes on principles of lifestyle intervention for preventing type 2 diabetes and obesity. Dietary intervention: 1 to 1 dietitian meetings, provision of daily menu for 5 days. Goal to increase PA from 15 to 30 min/day for first 4 weeks	Healthy lifestyle education to benefit type 2 diabetes and obesity prevention.	I=67%, C=64%	Decreased sedentary behaviour in favour of the intervention group	unknown
Spring et al. (2012) USA (1)	I= 53 I2= 44, C1=47 C2=48 Mean age: 30.8 ±10.8y Male and female	RCT 3 weeks Home based	4 arms of treatment - remote coaching supported by mobile decision support tech. and financial incentives. Participants needed to use a mobile device to self-monitor and attain behavioural targets to earn up to a $175. Used accelerometers and recorded diet and activity on the handheld device, which also used 'goal thermometers'. 4 treatment arms; increase F&V and PA; decrease fat and sedentary leisure; decrease fat and increase PA and; increase F&V and decrease sedentary leisure	Comparison between alternative treatment arms	I1 = 25%, I2 = 0%, C1= 4%, C2 = 0%	Significant reduction of sedentary behaviour in arm advocating increasing F&V and decreasing sedentary leisure compared to other arms	Financial incentive means results may not be repeated Some self-report measures

(1) Included in Martin et al. (2015) systematic review
(2) Included in Prince et al. (2014a) systematic review

Sedentary Behaviour Interventions

Study	Pop'n	Design and duration	Description	Control	Attrition	Authors con-clusion	Limitations
Otten et al. (2009) (2)	I = 20 C = 16 Mean age: 22 – 61 Male and females	RCT After 3 weeks of observation participants stratified by BMI and randomised to I or C for 3 additional weeks Home based	Restricted TV viewing time in the home of overweight and obese adults, examining the effects on energy intake (EI), energy expenditure (EE), energy balance, BMI and sleep levels. Participants wore portable devices that measured physiological and movement parameters. TV viewing reduced by 50% compared to objectively measured baseline level, enforced by an electronic lock-out system	Continued normal TV viewing habits	0%	IG significantly decreased time in sedentary activities, 153 min/day less sedentary time	Short term No long term follow up No report on acceptability of this intervention Financial reward for completing phases means results may not be repeatable

(2) Included in Prince et al. (2014a) systematic review

APPENDIX 6

Smart-phone Interventions Reporting Sedentary Behaviour Outcomes as Part of the Systematic Review by Free et al. (2013)

Study	Pop'n	Design and duration	Description	Control	Attrition	Authors con-clusion	Limitations
Shapiro et al. (2008) USA	I =31 C = 22 Mean age 8.4 – 9.3y Male and female	Parallel group RCT Home based After 3 weeks of observation participants stratified by BMI and randomised to I or C for 3 additional weeks.	Children and parents being prompted to self-monitor three behaviours; screen-time, sugar beverages and using a pedometer, through a short messaging service (SMS)	Undertook self-monitoring using a paper diary	46%	Children preferred a tailored, interactive program v paper diary; families in the IG completed 43% of requested self-monitoring v only 19% in CG	Incomplete outcome data Low quality study High attrition rates
Fardi et al. (2008) USA	I = 15 C = 15 Patients with type II diabetes	Pilot controlled trial 3 months Primary care/home	Daily text messages prompting patients to enhance their diabetic self-care, following uploading information on their glucose readings and step counts to a server	CG continued with standard diabetes self-mgt and tracked step count via pedometer	87%	Secondary outcomes included changes in time standing and sitting - no statistically significant effects	Extremely high attrition, technology not user-friendly, users lacked experience or confidence
Turner-McGrievy (2009)	I = 41 C = 37 Mean age: 37.7 – 39.6 O/w male and females	RCT 12 week	24 episode podcast programme underpinned by social cognitive theory designed by researchers	Standard weight mgt podcasts	21%	No significant sedentary behaviour changes differences between groups	Short term Self-report measures

APPENDIX 7

Smart-phone Trials
(Not Part of Systematic Reviews)

King et al. (2013)

80 middle aged adults (aged 45+) were recruited to an 8 week experimental study using 3 smartphone apps designed around behavioural science theory:

- An 'analytical' app focused on goal setting, self-monitoring and problem solving around barriers;
- A 'social' app compared other users' activity and offered support;
- An 'affective' app used +/- reinforcements and emotional transference to an avatar (an animated character) on the smartphone, reflecting the activity and sedentary behaviour of the user.

Displays gave 'just-in-time' feedback, activity assessments through an accelerometer and different reinforcements. Post intervention, 74% of participants reported that the apps had motivated them to sit less and 87% had found them easy to use.

Results: TV viewing time was measured as a proxy for sedentary time. Reductions in daily TV viewing time averaged 29.1 ± 84.5 minutes across the apps (but were not statistically significant between the groups), with less of an effect from the 'affective' app.

The limitations of this study are a small sample size, no control group and short duration. The authors acknowledge that a longer trial would be useful to test longer term maintenance of behaviour changes.

Bond et al. (2014)

30 overweight/obese participants took part in a 4 week experimental 'within-subjects design' trial comparing 3 approaches to promoting breaks and feeding back on sedentary time.

Participants wore accelerometers and were presented with three prompted breaks; a 3m break after 30m sedentary; a 6m break after 60m sedentary and a 12m break after 120m sedentary. $100 was given following required visits.

Once sedentary limits were reached, the smartphone delivered an on-screen reminder to take a break. If the break was taken, a message was sent to praise the accomplishment.

Results: Sedentary time reduced (between 3-6% from baseline) with the 3m break after 30m sedentary prompt being more effective. The study's limitations, however, include no control group, a small sample size, financial rewards artificially increasing motivation to change and no long-term follow up. It is not known therefore, whether these reductions in sedentary behaviour are sustainable.

Pellegrini et al. (2015)

8 type II diabetics were recruited to a small 4 week pilot feasibility study. Participants wore an accelerometer and used an app called *NEAT!* When 20m of sedentary time was recorded, the app initiated a noise/vibration, encouraging participants to stand up. Participants could choose responses; stand, extend sedentary time, cannot stand or ignore. If participants selected 'stand' on the app but did not, the accelerometer noted this and the app sent reminders every 2 minutes.

In 7 participants sedentary time decreased by 8.1 ± 4.5% ($p=0.003$) from baseline to the end of the study. Participants reported favourable experiences, however, barriers included a short battery life and the smart phone and accelerometer occasionally not working. As time progressed, the number of sedentary breaks taken decreased, whereas the break duration increased.

Participants responded to 62% of the number of prompts to stand, indicating the reminders were effective in breaking up prolonged sitting over half of the time. Due to the very low sample size, no definitive conclusions can be drawn, however, this study suggests this kind of technology could be a feasible and acceptable tool.