

Chapter 15

An Ecological Model for Understanding and Influencing Sedentary Behaviour



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Abstract With the evidence that time spent sitting can have adverse health consequences, a research priority is to build the requisite knowledge base for effective interventions—that is, what needs to be changed in order to change sitting time? To do so requires an understanding of the environmental and contextual determinants of sedentary behaviours, particularly to guide broad-reach public health approaches. Conceptual models that focus explicitly on environmental and contextual factors can assist in developing this key element of the overall sedentary behaviour epidemiology research agenda. Sedentary behaviours can usefully be understood as inherently context-specific—taking place in domestic environments, during transportation, and in educational and workplace environments. Within this perspective, an ecological model that emphasises the role of ‘behaviour settings’—context-specific environmental influences—has relevance. This chapter presents an approach informed by a behavioural epidemiology framework, drawing on evidence about sedentary behaviour and health, and about the contexts of time spent sitting. The aim is to provide an understanding of the environment- and policy-relevant determinants of sedentary behaviour (considered distinctly, but not separate from personal and social factors). To demonstrate how this approach can be helpful, we apply the five principles of an ecological model to sitting in the workplace. We outline how this model can provide an environmentally focused perspective and help to direct attention to multiple levels of influence on sedentary behaviour, and present an example of a workplace sitting-

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reduction intervention. We discuss some of the strengths and limitations of an ecological/environmental approach and suggest opportunities for future research.

What Is New?

- Evidence of differential associations of sedentary time in different environmental settings with health risk biomarkers and mental health indices.
- Identification of modest but statistically significant links of sedentary behaviour with neighbourhood environment attributes.
- Recent intervention trials in the workplace setting have employed environmental and ecological approaches, and have targeted multiple levels of influence.

15.1 Introduction

As noted in other chapters, research into all aspects of sedentary behaviour has increased considerably in recent years. There is now a substantial body of sedentary behaviour epidemiology evidence linking high levels of sitting with increased risk of a number of chronic diseases, risk factors and premature mortality. Furthermore, evidence from experimental studies in laboratory settings has begun to confirm and elaborate upon the implications of this observational-study evidence (see Chap. 5 for further detail). These findings point to the need for intervention trials to identify the feasibility and benefits of changing sedentary behaviours [1–5].

As with research involving other health behaviours, conceptual frameworks—models and theories—can assist in explaining and predicting sedentary behaviour, and can provide strong guidance for developing interventions. With the rapidly strengthening evidence base on the adverse health outcomes associated with sedentary behaviours, greater attention now needs to be focused on understanding the factors that influence too much sitting—the *determinants of sedentary behaviours*. Specific knowledge of the antecedents of sedentary behaviours in the *contexts in which they take place* is crucial to the design and implementation of effective evidence-based interventions. The application of theories and models to the study of sedentary behaviour is central to developing this stage of the research agenda.

To place the focus of this chapter in the perspective of sedentary behaviour epidemiology, Fig. 15.1 outlines the *behavioural epidemiology framework* [6–8]. This framework proposes six main phases of research on sedentary behaviour and their interrelationships. For example, understanding the important influences on particular sedentary behaviours (Phase IV) associated with adverse health outcomes (as identified within Phase I) will assist judgements about how difficult or how easy it may be to change them. Or conducting real-world assessments of the impact of manipulating such influences through intervention trials (Phase V) can provide strong clues for possible research directions on the determinants of behaviour.

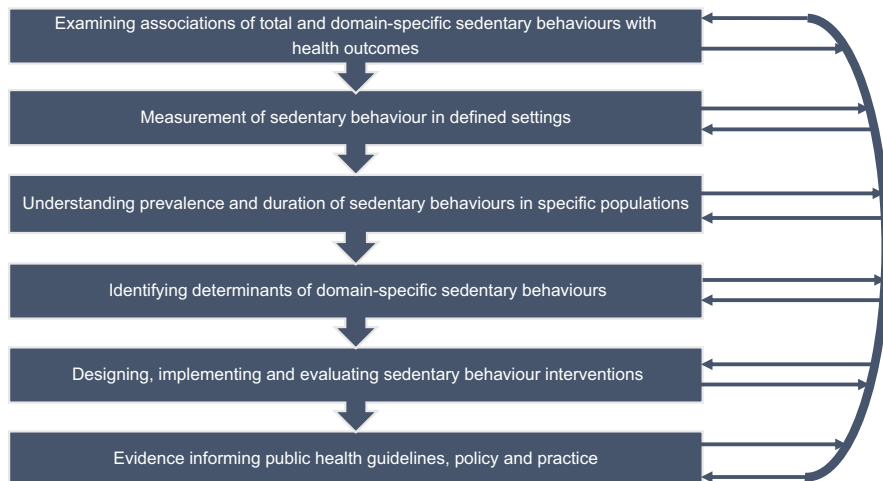


Fig. 15.1 Behavioural epidemiology perspective on understanding and influencing sedentary behaviours [6–8]

A key underpinning of the framework shown in Fig. 15.1 is that all of these phases of research can inform and influence each other. In this chapter, we will focus on the relevance of ecological models for informing research in Phases IV and V of the behavioural epidemiology framework, where the evidence base is more limited.

Research in Phases I through to VI, as illustrated in Fig. 15.1, may be thought of as a logical sequence of evidence building. However, considering the set of arrows on the right-hand side of the figure, this perspective on sedentary behaviour epidemiology research should not be taken to imply that each respective phase will require evidence from the preceding phases as essential building blocks. As evidence emerges on sedentary behaviour determinants and interventions (Phases IV and V) for example, this may point to fruitful new research directions identifying health outcomes and relevant mechanisms (Phase I), or as the policy context around sedentary behaviours is elaborated (Phase VI), research on determinants of sedentary behaviour (Phase IV) may require a different focus and novel opportunities for intervention trials (Phase V) may arise.

This chapter outlines a strategic perspective for research employing theories and models in the sedentary behaviour field. Specifically, we use particular illustrations of how conceptual frameworks can assist in progressing our understanding of the factors that can influence sitting, and can strengthen, in practical ways, the knowledge base underlying interventions. *This requires a conceptual perspective to capture the complexity of the determinants of sedentary behaviours across the key settings in which they occur.* We propose an ecological model of sedentary behaviour [9] as a framework for guiding future research studies. We employ this model throughout this chapter and demonstrate how it can be used to progress knowledge in the field.

Research in this relatively new and emerging field of sedentary behaviour epidemiology has been informed by theories and models used in physical activity

research [10, 11]. However, as we will discuss, there are unique characteristics of sedentary behaviour that suggest the need for a distinct, strategic approach to guide future research.

15.2 Strategies for Understanding Sedentary Behaviour

Research into the determinants of sedentary behaviour can be seen as both related to and distinct from research on physical activity and exercise. For the purposes of this chapter, when we refer to ‘physical activity’ we are generally referring to activity performed at a moderate-to-vigorous intensity—activity that increases heart rate and is often performed as planned bouts, which would be inclusive of ‘exercise’. While we make a clear and explicit distinction between physical inactivity (too little exercise) and sedentary behaviour (too much sitting), we understand that these are two distinct attributes that nevertheless may mutually influence each other, with synergistic behavioural, physical and mental health impacts that can be influenced by the environmental context and the attributes of the sedentary behaviours involved [12–15].

15.2.1 *Physical Activity and Sedentary Behaviour: Some Key Differences*

Interventions designed to increase physical activity or reduce sedentary behaviour have a common goal: to reduce the population-wide chronic disease burden associated with inactivity. Both approaches generally aim to encourage people to introduce more activity into their day, although the intensity of that activity is likely to differ. Sedentary behaviour interventions are designed primarily to support people to shift some of their sitting time to light-intensity activities, such as standing or walking; physical activity interventions have a greater focus on encouraging participants to accumulate more moderate-to-vigorous physical activity.

While there are close links between physical activity and sedentary behaviour, there are key qualitative differences between the two behaviours that underpin the need for novel strategies to guide research on sedentary behaviour interventions. In this context, Biddle and Gorely [16, 17] provide an informative elaboration of some of the distinctions between the nature of the relevant behaviours and the factors likely to determine these behaviours, for moderate-to-vigorous physical activity and for two specific examples of sedentary behaviour:

- *Moderate-to-vigorous physical activity*: Low frequency and short duration, often taking place as a bout on one occasion (or fewer) each day. It requires both conscious planning and moderate-to-high effort to carry out and is likely to be influenced by factors at multiple levels including individual-level goals and motivation, social support and a supportive physical environment.

- *Domestic sedentary behaviour (television viewing and other screen time)*: Occurs in regular prolonged bouts, typically in the evening and on weekends for working adults. It can be of long duration, in bouts of 2–3 h with infrequent breaks. It requires a low level of effort and little conscious planning. It is highly habitual and influenced by individual preferences, by social norms and typically by the physical environment—including furniture arrangements—of domestic settings.
- *Occupational sedentary behaviour (workplace sitting)*: Takes place in regular prolonged bouts for office workers, typically occurring on weekdays. It is often of very long duration—6–7 h accumulated across a day with infrequent breaks. It requires minimal effort or conscious planning and is highly habitual. Key drivers include habit, social norms, job requirements (such as computer-based work), and the workplace physical environment (including office furniture and spatial design features).

As noted above, there are some key differences in the relationships of environmental contexts with moderate-to-vigorous physical activities compared to sedentary behaviours—particularly related to the contextual factors that are likely to influence the frequency and duration of the two behaviours. Sitting is highly frequent and can occur in long bouts that may only be interrupted briefly for a short duration. In contrast, physical activities (specifically those of a moderate-to-vigorous nature) tend to occur at lower frequencies in relatively short, distinct bouts (e.g. 30 min to 1 h). An active person may go to the gym for an hour, four times a week, but may do little physical activity outside of these sessions. Importantly, the influencing factors or drivers of these behaviours are likely to differ, including the relative importance of habit and individual motivation.

Even the two examples of sedentary behaviour provided—TV viewing/screen time and workplace sitting—are likely to be influenced by different factors. Biddle and Gorely [16] suggest that this key difference in the level of conscious processing is likely to have implications for the application of particular theories of behaviour in relation to sedentary behaviour. While approaches for physical activity have typically focused on the role of conscious decision-making, individual-level theories for sedentary behaviour may need to have a greater focus on the importance of habit, or unconscious decision-making.

As outlined above, physical activity and sedentary behaviour should not be treated simply as two sides of the same coin [18, 19]; inactivity (low/insufficient levels of moderate-to-vigorous physical activity) is not the same as being sedentary (high levels of sitting). It is possible, for example, to be both highly sedentary and highly active (consider an office worker who cycles to work and then sits at a computer for long, unbroken blocks of time). Recognising the distinct determinants of physical activity and sedentary behaviour is particularly important for understanding these behaviours and appropriately intervening [8, 9, 16]. Influencing sedentary behaviour requires specific, targeted approaches based on the rapidly progressing research in this field, rather than just applying the approaches that have previously been found to be effective for understanding physical activity.

15.2.2 Identifying Determinants of Sedentary Behaviour: A Population-Health Perspective

The current sedentary behaviour epidemiology knowledge base provides indications of possible correlates (cross-sectional associations or predictors) of sedentary behaviour. Considerably less evidence exists on ‘determinants’ of sedentary behaviour [20]—a term implying a cause-and-effect relationship of one or more attributes with the probability or the extent of engagement, in a particular sedentary behaviour [21].

Of the correlates that have been identified, the most consistent evidence relates to individual-level factors, such as socio-demographics and health behaviour-related attributes [22]. Please refer to Chap. 2 for further details on the correlates of sedentary behaviour. Evidence for environmental correlates of sedentary behaviour is increasing, although this has largely been limited to exploring associations with the neighbourhood-built environment [20]. The relationship between interpersonal or social influences with sedentary behaviour is also less clear from existing quantitative studies. A review by O’Donoghue and her colleagues [20] found that family-related factors, specifically household composition and the presence of children, appeared to be associated with sedentary time but found no evidence to support an association between social norms or social interactions with non-family members (e.g. colleagues and friends) with sedentary behaviour, although the number of studies reviewed was small.

Interestingly, findings from qualitative research provide some additional evidence to suggest that aspects of the sociocultural and physical environmental may be important influences of behaviour. Interviews with office-based workers suggest, for example, that perceived social norms linking productivity with being at one’s desk create a barrier to taking more regular breaks from sitting [23], while supportive social environments may facilitate reduced sitting time. In addition, office furniture that feasibly only allows computer-based work to be performed seated is likely to be a key factor influencing sedentary behaviour in office-based workers [24, 25].

Another example of informative qualitative evidence on social attributes is the study by Chastin and his colleagues [26], who reported how social influences may play a significant role in influencing sedentary time for older adults. The older women interviewed for their study identified perceived societal expectations that older adults should sit frequently, combined with insufficient environmental features to accommodate brief pauses from sitting, as key factors influencing the amount of time they spent sitting. A further nuance is that older adults’ sitting varies significantly across the day, likely reflecting the interactions of settings, social and physical health influences [27, 28].

While the above provides snapshots of the evidence pertaining to interpersonal determinants of sedentary behaviour (which are addressed in more detail in Chaps. 2, 14, 16 and 28) it highlights the need to broaden thinking beyond individual-level factors and attempt to identify potentially modifiable environmental and social influences on sedentary behaviour. Conceptual models of the social and environmental determinants of sedentary behaviour can assist with this process, but need to

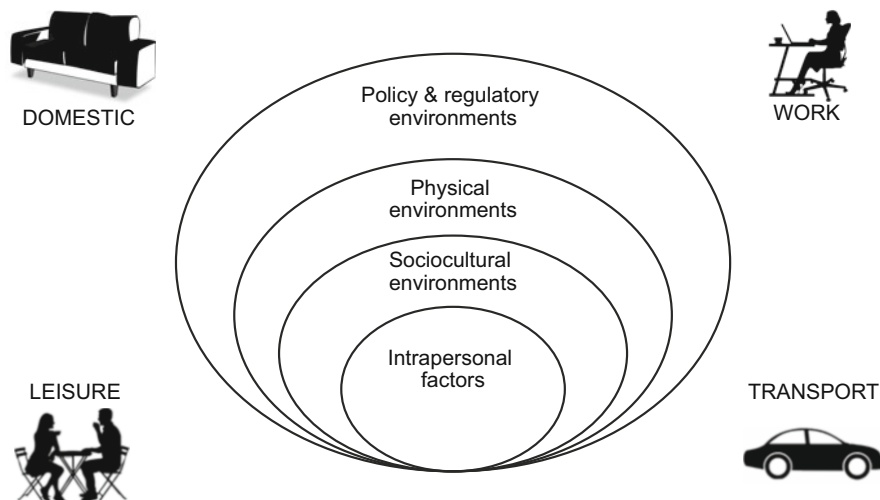


Fig. 15.2 A simplified ecological model of health behaviour (Reproduced with permission from Springer Nature) [32]

incorporate such nuances and complexities, including the differences that may emerge across the wide range of different settings in which these behaviours take place [29, 30] and the interaction between different levels of influence [20, 31].

As we will illustrate in the following section with reference to Fig. 15.2, there are challenges in taking an explicit social and environmental perspective on the determinants of sedentary behaviour. This reflects, in part, some of the roots of research in our relatively new sedentary behaviour field. Within physical activity research, individual-level theoretical models primarily have been employed in the design of interventions [6]. For example, social-cognitive approaches include strategies to try and increase participants' self-efficacy for physical activity, such as using goal setting and feedback on performance to alter participants' belief in their capability to undertake physical activity [33].

However, strategies that only target factors influencing behaviour at the individual level and fail to take account of the broader social and environmental context in which it occurs will not be sufficient to achieve changes that are of public health significance. In order to appropriately target such a prevalent and ubiquitous behaviour in a population health context, it will be necessary to incorporate an understanding of multiple levels of influences across different settings.

As noted earlier, there are still a number of gaps in our understanding of the determinants of sedentary behaviour; the evidence for this phase of the behavioural epidemiology framework is comparatively less developed than the preceding phases [34]. As an example, while a large body of research has focused on understanding attributes associated with TV viewing time or overall sitting time [16, 20, 22], less research has explored likely determinants of occupational sitting (despite the significant contribution of this setting to many adults' overall levels of sitting). Other

chapters in this book address the current state of knowledge relating to correlates of sedentary behaviour at the individual level (Chap. 16), the community level (Chap. 23) and related to the social and physical environment (Chap. 24).

We suggest that the use of an ecological model for sedentary behaviour may assist in addressing some of these research gaps and improving our understanding of the underlying determinants. Understanding the determinants of sedentary behaviours across different settings is particularly important as the factors that influence the amount of sedentary time a person engages in and related health consequences may depend on the specific setting in which it takes place [35].

15.3 An Ecological Model of Health Behaviour

Ecologic models have been used to explore and address a number of different health behaviours, including physical activity, healthy eating and tobacco smoking [36]. These ecological approaches largely arose after recognition that methods focused predominately on individual-level factors failed to achieve inroads in promoting healthy behaviours [36, 37].

Ecological models aim to recognise the complexity of health behaviours, acknowledging that there is unlikely to be a single cause-and-effect pathway. In line with approaches used to address some of these other health risk factors, the application of an ecological model to sedentary behaviour may also assist in guiding future research and identifying novel intervention targets across the multiple levels of influence.

A key distinction is that while individual-level models emphasise the role of person-level attributes (e.g. motivation, self-efficacy) that influence individual behavioural choices, ecologic models focus to a greater extent on individuals' interactions with their physical and sociocultural environments [38]. According to this notion, the act of motivating or educating a person to change their behaviour is expected to be limited if social and environmental conditions are not also supportive of this behaviour. However, while supportive environments are considered *necessary* for healthy behaviours, the idea that there are multiple levels of influence on behaviour means that altering the environment on its own may not be *sufficient* for behavioural change [39].

Ecological perspectives of health behaviour have five key principles that can be used to guide research and understand the precursors to behaviour [36, 39]:

1. There are multiple levels of influence on health behaviours
2. Environmental contexts are significant determinants of health behaviours
3. Influences on behaviours interact across levels
4. Ecological models should be behaviour-specific
5. Multi-level interventions should be most effective in changing behaviours

15.3.1 Applying an Ecological Model: Multi-level Approaches for Understanding the Determinants of Sedentary Behaviours

It has been noted previously that the choice of approaches for addressing health behaviour interventions tends to be influenced by disciplinary backgrounds of researchers rather than what may necessarily be the best approach [40]. For example, psychological influences highlight the importance of individually focused solutions to addressing health behaviours, while a practitioner from an urban design background may emphasise the importance of environmental influences on behaviour [41]. A disadvantage of this approach is that it has the tendency to lead to narrow, silo-type approaches to analysing problems and developing solutions [40].

Increasingly, it is being recognised that behavioural health risk factors such as insufficient physical activity and excessive levels of sedentary behaviour are complex problems, requiring multi-faceted solutions. To address these issues, we therefore require theoretical frameworks that can recognise and incorporate this complexity [42]. We suggest that ecological models are better suited to this task when compared with individually focused models and can provide the framework for developing appropriate interventions.

Importantly, ecological models have much in common with best-practice health promotion approaches. The Ottawa Charter for Health Promotion [43] emphasises the importance of multi-faceted approaches, suggesting that the ideal conditions for encouraging healthy behaviours include supportive environments and policies, and ensuring that individuals are educated, but also that they have sufficient resources to make healthy choices. The national preventive health framework in the USA, *Healthy People 2030*, outlines the importance of addressing the social, environmental and economic determinants of health, in addition to individual-level factors [44]. In line with these approaches to preventive health and health promotion more generally, an ecological model may also be beneficial for guiding research and interventions into the new public health challenges posed by excessive sedentary behaviour, with ultimate translational relevance.

15.3.2 Ecological Model Principles and Individual-Level Theories

Ecological models do not discount that individual-level characteristics, such as motivation or individual preferences, may influence sedentary behaviour. Social-cognitive theories formed the basis of many interventions that have aimed to encourage higher levels of physical activity in the population [36]. The direct application of social-cognitive theories to sedentary behaviour is still somewhat limited [34]. However, there is some evidence to suggest that dual-process theories may be helpful for understanding some of the cognitive influences on sedentary

behaviour. Dual-process theories propose that we have two processing pathways—one automatic and non-conscious and the other controlled and reflective. As discussed earlier, it is highly probable that automatic, cue-driven processing plays an important role in sedentary behaviour, whereas physical activity, which occurs in less frequent bouts, may involve more controlled processing [16]. Some studies have found evidence to support an association between habits and sedentary behaviour amongst university students [45] and older adults [46] where those with stronger habits reported spending more time sitting. Interestingly, the application of a form of controlled processing—having specific intentions to reduce sedentary behaviour—was associated with lower levels of sitting time in both samples [45, 46], suggesting a possible explanation for some of the variation in sedentary behaviour, and a pathway to explore within interventions.

However, a limitation of individual-level theories, including the dual-process model, is that their specificity does not account for the broader social and contextual attributes that can influence behaviour. While an ecological model does not discount the role of cognitive processes in influencing behaviour, it is considered that individual attributes are only one level of influence of sedentary behaviour and should not be considered in isolation from contextual factors that are also likely to be influential. From an ecological perspective, approaches centred on solely educating individuals about the health consequences of their behaviour and motivating them to change are not expected to be sustainable in the long term, unless combined with strategies targeting the broader environmental, social and policy context in which the behaviour occurs [36].

15.4 An Ecological Model of Sedentary Behaviour

An ecological model of sedentary behaviour identifies four domains—*leisure*, *household*, *transport*, and *occupation* [9]. The range of potential influences and their relative importance is considered to differ in each of these domains [9]. This is based on a preceding ecological model of physical activity behaviour. Figure 15.2 depicts a simplified version of the main levels of influence that ecological models identify. This perspective directs research attention to broader potential influences on sedentary behaviours, beyond the more usual focus on individual-level attributes that are addressed by psychological and social-cognitive theoretical models [34].

As previously stated, a key underpinning of ecological models is the emphasis on environmental and social factors as important influences of behaviour. While the empirical evidence for environmental determinants of sedentary behaviour is still emerging [20], the habitual, unconscious nature of many instances of sedentary behaviour leads to the hypothesis that particular cues in our environment act as triggers for sitting. When one takes the time to think about what influences sitting throughout the day, this makes some intuitive sense. For example, are you sitting down right now while reading this chapter? If so, perhaps this is because you are at a desk—at home, in the library, or at your workplace—which is at a fixed height

designed for use with a chair. Perhaps you are also sitting down because this is the behaviour demonstrated by others in your environment and social norms encourage you to emulate that behaviour. The social norms around what is ‘normal’ or ‘acceptable’ behaviour are likely to be important influences of when and where we sit, as they are with other behaviours. An emerging body of literature has investigated the application of choice architecture techniques, or ‘nudging’, to the field of sedentary behaviour and physical activity, whereby small changes are made to micro-environments (such as home settings and workplaces) to promote behavioural change [4, 17]. More research (including high-quality, controlled trials) is needed to ascertain whether such strategies could be effective for changing sedentary behaviour.

15.4.1 The ‘Behaviour Settings’ Construct Within an Ecological Model of Sedentary Behaviour

The potential utility of an ecological model for sedentary behaviour also arises from the importance that it places on ‘behaviour settings’ [47]—the physical and social context in which sedentary behaviour takes place. The complexity of understanding and influencing sedentary behaviour stems from the reality that sitting occurs in numerous contexts and a blanket approach targeting ‘sedentary behaviour’ fails to take these nuances into account. Common examples of sedentary behaviours—such as watching television, driving a car and sitting at a desk at the workplace are each likely to have distinct determinants and require different approaches [9]. The relative importance of each of these settings is also likely to differ across population groups. For working adults in sedentary jobs, intervening in the workplace setting may have the biggest impact on total daily sitting time [48]. For retirees, the household setting is often where the largest proportion of sedentary time occurs and thus intervening in this setting may be most effective [49]. For adults living in outer suburban areas, addressing time sitting in motor vehicles may be fruitful [31]. Feasible strategies for reducing sitting are also likely to differ between settings. In the workplace, for example, activity-permissive workstations are often trialled [50], while in the home environment feasible strategies may include encouraging people to take more frequent breaks from sedentary leisure activities (such as standing up and moving during commercial breaks or between episodes [51]). For further details on sedentary behaviour interventions targeting different population subgroups and settings, please refer to this chapter.

Further empirical evidence is needed to test the principles of an ecologic model of sedentary behaviour as outlined above. Using the ecologic model as a guide, there are opportunities for novel research questions about the possible determinants of sedentary behaviour in each of the common domains. This evidence will further our understanding of this highly prevalent health risk factor and provide an important knowledge base to inform settings-based interventions.

15.4.2 Environmental Influences on Sedentary Behaviour

When thinking about environmental influences on behaviour, these can include perceptions and objectively measured aspects of the built environment, the natural environment and the sociocultural environment. There is a body of research linking aspects of the built environment, particularly population density and access to destinations, with walking [52], sedentary time [53] and cycling for transport [54].

A review of the evidence linking neighbourhood environmental attributes with sedentary behaviours by Koohsari and his colleagues [31] found somewhat mixed evidence. Less than 30% of instances examined were significantly associated in the expected direction (i.e. environmental attributes more favourable to physical activity being associated with lower levels of sedentary behaviour). Many of the studies found no evidence for the expected associations. One possible explanation that was suggested was a lack of correspondence between the setting (neighbourhood environment) and the behaviours measured in the studies; the sedentary behaviour outcome was frequently an assessment of total sitting time accumulated across the day. In accordance with the ecological model, it would be expected that neighbourhood environment features would be most relevant to behaviour that occurs in that setting (i.e. the home) and would not necessarily influence behaviour in other settings, such as the workplace. The review recommended the need for improved measures of sedentary behaviour and environmental attributes (objective rather than self-report) and more prospective study designs. In addition, the limited understanding of possible interactions between environmental factors with other levels of influence on sedentary behaviour, such as socio-demographic characteristics, was also noted. The review also highlighted the need for studies to consider a distinct analytic approach for understanding the determinants of sedentary behaviour, rather than viewing it as simply a contrasting behaviour to physical activity.

The review by Koohsari et al. did not include studies assessing environmental features of internal environments such as the workplace or home environment. This is an important research gap as altering the indoor environment—such as through replacing traditional seated desks with height-adjustable desks—has become a key focus of many interventions to reduce sedentary time. An ecological approach may assist in identifying the specific, and potentially distinct (indoor and outdoor), environmental determinants of sedentary behaviour in key settings and thus provide a stronger underlying evidence base for this growing field.

15.4.3 Application of an Ecological Model in Sedentary Behaviour Research: The Workplace

To illustrate how the ecological model can assist in guiding research and understanding of sedentary behaviour, we will use the workplace as an example. As will be discussed in further detail in Sect. 15.2, of the key domains of sedentary

behaviour [18], the workplace is of particular interest, largely due to the volumes of time that adults spend in the workplace and the increasingly sedentary nature of jobs.

The Workplace as a Sedentary Behaviour Setting

For those in office-based jobs, at least two-thirds of working hours can be spent sedentary [55–57]. Thus, workplace sitting on its own contributes a significant proportion of total daily sitting time for many adults. Reducing the amount of time that people spend sitting at work may therefore have broad-ranging effects on population levels of sedentary behaviour. Sedentary behaviour in the workplace may also be amenable to change, relative to sedentary behaviour occurring in other settings, as it occurs within a regulatory context where employers have legal responsibilities for the health and safety of their employees. Indeed, researchers in this field have called for sedentary behaviour to be considered explicitly as an occupational health and safety issue and treated accordingly within this framework [58].

The workplace has been used as a setting for implementing strategies targeting a range of health risk behaviours including physical activity, nutrition and tobacco control [10]. Working adults spend a significant proportion of their waking hours at work and can be viewed as a captive audience for these messages [59]. For employers, implementing health promotion programs in the workplace can make good business sense, with the potential for economic benefits arising from lower workplace injury rates, reduced absenteeism and greater staff retention [60].

In workplace health promotion, ecological models are consistent with best-practice guidelines. For example, the World Health Organization's Healthy Workplaces Model [61] identifies four areas to incorporate into strategies for improving workplace health: the *physical workplace environment*, the *psychosocial work environment*, *personal health resources* and *enterprise community involvement*. These four pillars emphasise the importance of considering the multi-level influences on health behaviour, in line with principles of an ecological model of health behaviour. In Sect. 18.2, examples will be presented of how a sedentary behaviour program can address the keys to a healthy workplace outlined by this model.

The value of using an ecological model for thinking about the possible determinants of behaviour is that, from the outset, we are challenged to consider how multiple different levels of influence may be involved. Rather than just focus on the most conspicuous factors or those in a particular disciplinary area, an ecological model can encourage a broader, multidisciplinary perspective that can take into account factors that may not previously have been considered.

An ecological model also aligns with our understanding of the workplace as a complex social system [62]. Sedentary behaviour, like other behaviours that occur in this setting, is likely to be influenced by a range of factors including individuals' health status and motivations, beliefs, social norms, social climate, environmental features, and organisational policies and procedures [62–64]. To give an example of how an ecological model of sedentary behaviour can be applied, we will now step

through the five principles of ecological models as they apply to the workplace. For illustrative purposes, we focus on office-based workplaces.

1. There are multiple levels of influence on health behaviours

Thinking about how much time we spend sitting at work, we can identify a range of factors that influence this behaviour. Many of us rely on computers to perform our work, and the typical furniture setup to facilitate this work is a desk and chair. Thus, environmental influences are prominent. However, we can also consider individual-level factors. Some might enjoy sitting down and find this a more comfortable posture than standing. We may have health-related issues that are benefited by sitting. Social norms are also likely to be influential. Perceptions of expected behaviour in the workplace (e.g. that workers are not productive unless they are at their desk) or fear of not wanting to stand out by behaving differently (e.g. by getting up more frequently to stretch or move around the office) may also play a role [23, 24].

2. Environmental contexts are significant determinants of health behaviours

The environmental features of the workplace are likely to be important contributors to the amount of time spent sitting. As mentioned above, fixed height desks often limit workers' ability to stand or move throughout their workday. Furniture in meeting rooms and office kitchens is often designed for sitting. Other aspects of the physical environment, such as the location of communal equipment (e.g. printers, bins, kitchens, bathrooms), can encourage or limit the opportunities that people have to move away from their sedentary desk work. The availability and accessibility of staircases as an alternative to lifts is another environmental factor influencing activity more generally.

3. Influences on behaviours interact across levels

As outlined, we can identify multiple different influences of sedentary behaviour in the workplace. There is also evidence to suggest that these factors are likely to interact across levels as specified by the ecological model. Studies that have explored barriers and enablers to using height-adjustable desks in the workplace provide some indication of this phenomenon. One study found that workplaces that simply provided staff with height-adjustable desks with minimal other instruction had lower use of these desks compared to a workplace that supplemented the desks with education and encouragement of their use [65]. Similarly, interpersonal or social factors can interact with individual and environmental level factors to influence workplace sitting. Seeing others use their height-adjustable workstation can provide important social support that can encourage workers to stand up [66]—indicating an interaction between environmental and social influences. In contrast, negative interpersonal interactions (such as concerns about noise projection with standing) may also influence takeup or use of workstations that facilitate standing [66].

4. Ecological models should be behaviour-specific

When thinking about how to address sedentary behaviour, it is important to consider the setting in which it takes place. In contrast to the relative privacy and freedom of the home environment, behaviour in the workplace is influenced by a

Table 15.1 A multi-level intervention designed to reduce and break up workplace sitting in office workers: Stand Up Victoria

Level of influence	Strategies
Individual	<ul style="list-style-type: none"> • Face-to-face and telephone health coaching, focusing on goal setting and providing support, behaviour change strategies, instruction/demonstration on workstation use
Organisational	<ul style="list-style-type: none"> • Senior management and staff representative consultation • Participant brainstorming session to identify suitable strategies for that worksite • Leadership support and communication through tailored management emails
Environmental	<ul style="list-style-type: none"> • Sit-stand workstation

range of social norms, organisational policies and expectations about behavioural conduct. For many, the degree of volition we have with our behaviour differs markedly. For these reasons, the underlying models of behaviour underpinning strategies for addressing sedentary behaviour should differ between these two settings. This follows the underlying premise of ecological models—that they should be behaviour-specific. Even within the workplace setting, there are different contexts in which sedentary behaviour occurs that should be considered when planning interventions. Some examples of sedentary behaviour that occur in a workplace include sitting at a desk in front of a computer, sitting in a meeting and sitting in a kitchen/tearoom during a break. Each can be explained by multiple levels of influence; however, the relative importance of each of these levels may differ according to the behavioural context.

5. Multi-level interventions should be most effective in changing behaviours

While early research aiming to intervene on sedentary behaviour in the workplace focused attention on the discernible environmental influences by altering the physical workstations used by workers [67], there are some more recent examples of intervention development that have taken a broader approach along the lines of an ecological model. These provide some evidence that multi-level interventions may be more effective than those that just focus on a singular level.

The *Stand Up Victoria* study is an example of a workplace intervention targeting sedentary behaviour that was developed using an ecologic model of sedentary behaviour as the guiding framework [68]. The intervention involved an environmental component, but also targeted organisational and individual factors thought likely to influence sedentary behaviour (see Table 15.1). Within this ecological framework, social-cognitive theory was also used to guide the development of the intervention [68, 69].

The design of the study involved an initial 3-month intervention period (when the full multi-component intervention was applied), followed by a 9-month maintenance period. During the maintenance period, participants in the intervention group

retained their workstations; however, the other intervention components ceased at 3 months [69].

In recent years, an increasing number of studies have been conducted assessing the effectiveness of various activity-permissive workstations for reducing sitting. Generally, these have been shown to lead to reductions in sitting time [67, 70, 71]. However, as discussed in other chapters, there is evidence that a multi-component approach targeting influences at the individual, organisational and environmental level may lead to greater reductions in sitting time when compared with the provision of a sit-stand workstation in isolation [50]. This would support the premises of the ecological model, particularly the need to identify and target the multiple levels of influence on behaviour. Further research is needed to assess the relative importance and contribution of each of these different levels of influence in the context of sedentary behaviour interventions.

Stand Up Victoria has provided an example of how an ecological model can be used to guide sedentary behaviour intervention development, in contrast to initial intervention trials in the field which tended to use single-focus and/or individually oriented approaches [72]. It is also important to note that within the ecological framework used to guide the *Stand Up Victoria* approach, strategies designed using a social-cognitive theoretical approach were able to be incorporated successfully within a broader strategy addressing aspects of organisational, social and physical environments at work. The *Stand Up Victoria* project provided early evidence to demonstrate how interventions at multiple levels (Principle 5 above, arguably the strongest test of the utility of the ecological approach) may be carried out in practice.

15.5 Limitations of Models and Theories in Applications to Sedentary Behaviour

Models and theories can assist us to make sense of behaviour and the world around us. For behaviours that pose a risk to health, theories can help to provide a framework for understanding their underlying causes and guide intervention development. Broader models can assist with identifying relationships between different factors and understanding the pathways through which these impact on behaviour. Understanding these interactions can aid in identifying the most appropriate and effective intervention targets within complex causative pathways.

However, there may be inherent limitations with the use of currently available models and theories of behavioural and social sciences in the context of understanding the determinants of sedentary behaviour. Many theories that have been used to describe health behaviours focus on individual-level influences, including education and awareness-raising, motivation and other cognitive processes. When applied with a focus primarily at the individual level, they often do not account for the other levels of influence—social, environmental or policy—which may also encompass relevant

determinants of sedentary behaviour. For these reasons, the predominant social-cognitive models may provide a helpful but only partial account of the range of relevant determinants. For practitioners involved in designing an intervention, it can also be difficult to identify which of the multitude of theories available in the literature would be most useful or relevant for the health behaviour of interest.

Additionally, it may be unclear as to how such theories can actually be translated from the research environment into programs that can be scaled up and applied in real-world settings. The overall outcome of interventions aimed at reducing sedentary behaviour should be to ultimately effect change on a population level. As such, it is important to consider the need for theories and models to be accessible so that they can also be up-scaled and usefully translated to broader scale interventions, not just applicable in smaller scale laboratory studies.

15.5.1 Limitations of Ecological Models

We have emphasised the potential utility of an ecological model for understanding and influencing sedentary behaviour. However, although we have outlined the strengths of such a model, there are limitations. A key principle of ecological models is that there are multiple levels of influence, all of which are deemed to be important (albeit varyingly so, depending on the setting, the person and other factors). It has been suggested that when these models have been applied in practice there has at times been an exclusive focus on environmental influences. This parallels criticisms of individual-level models—that they provide a narrow, incomplete account of human behaviour [40]. Multidisciplinary research partnerships that involve team members with broad expertise in interests and backgrounds may foster research that is more true to a fundamental principle of ecological models: addressing multiple levels of influence and their interactions.

Another limitation of the application of models identifying multiple levels of influence is that they can be difficult to design, evaluate and measure, due to their complexity. Public health programs designed with an ecological framework in mind may feature large-scale environmental and policy changes that occur in natural, uncontrolled settings. What is delivered in practice often will be out of the hands of researchers and like many public health interventions will not be amenable to evaluations using controlled experimental methods. This poses challenges for evaluating the effectiveness of intervening on multiple levels and unpicking which components of which levels of the intervention are most effective [4, 5].

Nevertheless, this reflects the real-world complexity of the strategies likely to be necessary in order to make significant progress in addressing large-scale and complex public health issues. From a researcher's perspective, the use of an ecological model presents challenges as multi-level studies are complex and demanding. Teams from a broad range of disciplines are likely to be needed to provide the expertise on the different levels of influence and assist with measurement and analysis of these components. However, this could also be viewed as a positive step. It is increasingly

recognised that the public health challenges we face are multi-faceted and will not be successfully addressed by applying a narrow mind-set that focuses all attention on individual choice. By encouraging the framing of these issues through an ecological model, there is the opportunity to encourage researchers and practitioners from different backgrounds to collaborate, share perspectives and break down research silos. New insights and perspectives on approaching a particular challenging problem may arise from the opportunity to share knowledge across disciplinary areas.

A further limitation is that ecological models do not specify the processes through which different variables interact to influence behaviour. Unlike individual-level theories of the determinants of health behaviours, which specify within a formal framework the interrelationships between variables and how these are thought to determine behaviour, an ecological model does not provide this level of specificity. Sallis and Owen [36] propose that this is a key issue to keep in mind when applying ecological models; they should be viewed as guiding frameworks, rather than as explanatory theories. Instead of being a formal theoretical model, a key feature of ecological frameworks is that they can incorporate specific individual-level, more formally articulated theories into a broader framework.

Recognising some of the limitations of ecological models, there has been a broad collaborative project to develop a systems-based approach to understanding the multiple levels of determinants of sedentary behaviour and how they may interact [73]. This approach specifically aims to address the limitation that ecological models do not specify the connections between different levels of influences. Following a consensus process, some recommendations for priority research areas have been suggested.

15.6 Research Advances and Opportunities

There is still more to be done to further our understanding of the most effective ways to influence and reduce sedentary behaviour. There are some notable research advances in understanding key building blocks for an ecological approach to sedentary behaviour. Prominent in the newer body of evidence are examinations of environmental and related factors that can influence sedentary behaviour, and new analytic methods for making sense of the complexities of the relevant findings. These have been the topic of recent review papers [74–76]. Initial research using Bayesian network analysis applied to Eurobarometer data provides some insights into the complex interrelatedness between different levels of influence on sedentary behaviour [77]. This innovative approach suggests avenues for further research to extend the understanding of the various influences on sedentary behaviour, and how these differ across the life course and within specific behaviour settings. Recently reported findings on the outcomes of complex interventions including environmental elements are promising [78–80], with some optimism being expressed in recent reviews of qualitative and quantitative findings [81–83]. An approach showing promise is the application of choice architecture techniques, or ‘nudging’, to the

field of sedentary behaviour and physical activity [84]. The potential of such approaches for modifying sedentary behaviours will become more apparent through future research evidence.

From the ecological model and associated principles we have outlined in this chapter, we propose some key questions for research:

1. What are the broader and more generalisable social, environmental and policy level determinants of sedentary behaviour?
2. What specific social, environmental and policy level determinants are influential for the key ‘behaviour settings’—the home environment, transportation and the workplace/school?
3. Are there cultural or national level variations in the relative importance of individual, social, environmental and policy influences on sedentary behaviour?
4. How do environmental determinants of sedentary behaviour interact with other more well-studied levels of influence on health behaviours, such as personal characteristics and social influences?
5. Do environmental factors have differential strengths of influence on sedentary behaviours in some population groups compared with others? (For example, across different age groups; amongst those from different socioeconomic status backgrounds).
6. What is the feasibility of multi-level interventions in different settings—from design, implementation and evaluation perspectives?
7. Do interventions that target multiple levels of influence result in more sustainable changes than those that target single, or fewer, levels of influence?
8. What are the key sociocultural determinants of sedentary behaviour and how do these factors influence intervention effectiveness and sustainability?
9. What are the essential (and non-essential) components of multi-level sedentary behaviour interventions in the workplace that can achieve sustainable behavioural change?
10. What are the features of exemplary organisations (workplaces, schools, etc.) that have been successful in reducing sedentary behaviour?
11. How best to assess the quality and comprehensiveness of studies that report using an ecological framework?

15.7 Conclusions

An ecological model of sedentary behaviour can provide strong guidance in understanding how the determinants of sedentary behaviours in particular settings may be better understood and influenced. This evidence, in turn, can influence the development of interventions and strategies to address sedentary behaviour through a focus on improving health outcomes, in line with the six phases of the behavioural epidemiology framework (Fig. 15.1). While individual-level attributes that may be addressed with conceptual and methodological rigour using social-cognitive theories remain important, the field of sedentary behaviour epidemiology will advance in

ways more relevant to improving health outcomes if its research strategy proceeds using a broader multidisciplinary, ecologic perspective. Taking forward a rigorous and relevant research agenda within the framework of an ecological model of sedentary behaviour is challenging, and there are many new and potentially fruitful directions for research.

References

1. Tremblay MS, Colley RC, Saunders TJ, Healy GN, Owen N. Physiological and health implications of a sedentary lifestyle. *Appl Physiol Nutr Metab.* 2010;35(6):725–40.
2. Hamilton MT, Healy GN, Dunstan DW, Zderic TW, Owen N. Too little exercise and too much sitting: inactivity physiology and the need for new recommendations on sedentary behavior. *Curr Cardiovasc Risk Rep.* 2008;2(4):292–8.
3. Dunstan DW, Dogra S, Carter SE, Owen N. Sit less and move more for cardiovascular health: emerging insights and opportunities. *Nat Rev Cardiol.* 2021;18(9):637–48.
4. Owen N, Healy G, Dempsey PC, Salmon J, Timperio A, Clark B, Goode A, Koorts H, Ridgers ND, Hadgraft N, Lambert G, Eakin E, Kingwell BA, Dunstan DW. Sedentary behavior & public health: integrating the evidence and identifying potential solutions. *Annu Rev Public Health.* 2020;41:265–87.
5. Owen N. Emergence of research on sedentary behaviour and health. In: Zhu W, Owen N, editors. *Sedentary behaviour and health: concepts, evidence, assessment and intervention.* Urbana-Champaign, IL: Human Kinetics; 2016.
6. Sallis JF, Owen N. *Physical activity and behavioral medicine.* SAGE Publications; 1998.
7. Sallis JF, Owen N, Fotheringham MJ. Behavioral epidemiology: a systematic framework to classify phases of research on health promotion and disease prevention. *Ann Behav Med.* 2000;22(4):294–8.
8. Owen N, Healy GN, Matthews CE, Dunstan DW. Too much sitting: the population health science of sedentary behavior. *Exerc Sport Sci Rev.* 2010;38(3):105–13.
9. Owen N, Sugiyama T, Eakin EE, Gardiner PA, Tremblay MS, Sallis JF. Adults' sedentary behavior determinants and interventions. *Am J Prev Med.* 2011;41(2):189–96.
10. Rosenberg DE, Lee IM, Young DR, Prohaska TR, Owen N, Buchner DM. Novel strategies for sedentary behavior research. *Med Sci Sports Exerc.* 2015;47(6):1311–5.
11. Hadgraft NT, Owen N, Dempsey PC. Physical activity and public health. In: Detels R, Leyland A, Baum F, Li L, Quarraisha K, editors. *Oxford textbook of global public health.* 7th ed. London: Oxford University Press; 2021.
12. Dempsey PC, Hadgraft NT, Winkler EAH, Clark BK, Buman MP, Gardiner AP, Owen N, Lynch BM, Dunstan DW. Associations for context-specific sitting time with markers of cardiometabolic risk in Australian adults. *Int J Behav Nutr Phys Act.* 2018;15:114.
13. Sugiyama T, Hadgraft N, Clark BK, Dunstan DW, Owen N. Sitting at work and waist circumference: a cross-sectional study of Australian workers. *Prev Med.* 2020;141:106243.
14. Sugiyama T, Chandrabose M, Homer AR, Sugiyama M, Dunstan DW, Owen N. Car use and cardiovascular disease risk: systematic review and research agenda. *J Transp Health.* 2020;19:100930.
15. Hallgren M, Dunstan DW, Owen N. Passive versus mentally-active sedentary behaviors and depression. *Exerc Sport Sci Rev.* 2020;48(1):20–7.
16. Biddle SJH, Gorely T. Sitting psychology: towards a psychology of sedentary behaviour. In: Papaioannou AG, Hackfort D, editors. *Routledge companion to sport and exercise psychology: global perspectives and fundamental concepts.* East Sussex: Routledge; 2014.
17. Biddle SJH, Mutrie N, Gorely T. *Psychology of physical activity: determinants, well-being, and interventions.* 4th ed. London: Routledge; 2021.

18. Mielke GI, da Silva ICM, Gomersall SR, Owen N, Hallal PC. Reliability of a multi-domain sedentary behaviour questionnaire and comparability to an overall sitting time estimate. *J Sports Sci.* 2020;38(3):351–6.
19. Lynch BM, Healy GN, Dunstan DW, Owen N. Sedentary versus inactive: distinctions for disease prevention. *Nat Rev Cardiol.* 2010;7(11)
20. O'Donoghue G, Perchoux C, Mensah K, Lakerveld J, van der Ploeg H, Bernaards C, et al. A systematic review of correlates of sedentary behaviour in adults aged 18–65 years: a socio-ecological approach. *BMC Public Health.* 2016;16(1):1.
21. Bauman AE, Sallis JF, Dzewaltowski DA, Owen N. Toward a better understanding of the influences on physical activity: the role of determinants, correlates, causal variables, mediators, moderators, and confounders. *Am J Prev Med.* 2002;23(Suppl 2):5–14.
22. Rhodes RE, Mark RS, Temmel CP. Adult sedentary behavior: a systematic review. *Am J Prev Med.* 2012;42(3):e3–28.
23. Gilson ND, Burton NW, van Uffelen JG, Brown WJ. Occupational sitting time: employees' perceptions of health risks and intervention strategies. *Health Promot J Austr.* 2011;22(1): 38–43.
24. De Cocker K, Veldeman C, De Bacquer D, Braeckman L, Owen N, Cardon G, et al. Acceptability and feasibility of potential intervention strategies for influencing sedentary time at work: focus group interviews in executives and employees. *Int J Behav Nutr Phys Act.* 2015;12(1)
25. Cole JA, Tully MA, Cupples ME. "They should stay at their desk until the work's done": a qualitative study examining perceptions of sedentary behaviour in a desk-based occupational setting. *BMC Res Notes.* 2015;8(1):683.
26. Chastin SF, Fitzpatrick N, Andrews M, DiCroce N. Determinants of sedentary behavior, motivation, barriers and strategies to reduce sitting time in older women: a qualitative investigation. *Int J Environ Res Public Health.* 2014;11(1):773–91.
27. Van Cauwenberg J, Van Holle V, De Bourdeaudhuij I, Owen N, Deforche B. Diurnal patterns and correlates of older adults' sedentary behavior. *PloS One.* 2015;10(8):e0133175.
28. Kikuchi H, Inoue S, Sugiyama T, Owen N, Oka K, Nakaya T, et al. Distinct associations of different sedentary behaviors with health-related attributes among older adults. *Prev Med.* 2014;67:335–9.
29. Kozo J, Sallis JF, Conway TL, Kerr J, Cain K, Saelens BE, et al. Sedentary behaviors of adults in relation to neighborhood walkability and income. *Health Psychol.* 2012;31(6):704–13.
30. Mielke GI, da Silva IC, Owen N, Hallal PC. Brazilian adults' sedentary behaviors by life domain: population-based study. *PloS One.* 2014;9(3):e91614.
31. Koohsari MJ, Sugiyama T, Sahlqvist S, Mavoa S, Hadgraft N, Owen N. Neighborhood environmental attributes and adults' sedentary behaviors: review and research agenda. *Prev Med.* 2015;77:141–9.
32. Hadgraft NT, Dunstan DW, Owen N. Models for understanding sedentary behaviour. In: Leitzmann M, Jochem C, Schmid D, editors. *Sedentary behaviour epidemiology.* Springer series on epidemiology and public health. Cham: Springer; 2018. https://doi.org/10.1007/978-3-319-61552-3_15.
33. Ashford S, Edmunds J, French DP. What is the best way to change self-efficacy to promote lifestyle and recreational physical activity? A systematic review with meta-analysis. *Br J Health Psychol.* 2010;15(Pt 2):265–88.
34. Memon AR, Stanton R, To Q, Schoeppe S, Urooj A, Alley S, Hayman M, Vandelanotte C. Sedentary behaviour research in adults: A scoping review of systematic reviews and meta-analyses. *J Sports Sci.* 2021; <https://doi.org/10.1080/02640414.2021.1928382>.
35. Dempsey PC, Hadgraft NT, Winkler EA, Clark BK, Buman MP, Gardiner PA, Owen N, Lynch BM, Dunstan DW. Associations of context-specific sitting time with markers of cardiometabolic risk in Australian adults. *Int J Behav Nutr Phys Act.* 2018;15(1):1–1.
36. Sallis JF, Owen N. Ecological models of health behavior. In: Glanz K, Rimer BK, Viswanath K, editors. *Health behavior: theory, research, and practice.* 5th ed. Wiley; 2015.

37. Trost SG, Owen N, Bauman AE, Sallis JF, Brown W. Correlates of adults' participation in physical activity: review and update. *Med Sci Sports Exerc.* 2002;34(12):1996–2001.
38. Stokols D, Grzywacz JG, McMahan S, Phillips K. Increasing the health promotive capacity of human environments. *Am J Health Promot.* 2003;18(1):4–13.
39. Sallis JF, Owen N, Fisher EB. Ecological models of health behavior. *Health behavior and health education: theory, research, and practice.* Vol. 4. 2008. p. 465–486.
40. King AC. Theory's role in shaping behavioral health research for population health. *Int J Behav Nutr Phys Act.* 2015;12:146.
41. Adams MA, Frank LD, Schipperijn J, Smith G, Chapman J, Christiansen LB, et al. International variation in neighborhood walkability, transit, and recreation environments using geographic information systems: the IPEN adult study. *Int J Health Geogr.* 2014;13(1):1.
42. Owen N, Salmon J, Koohsari MJ, Turrell G, Giles-Corti B. Sedentary behaviour and health: mapping environmental and social contexts to underpin chronic disease prevention. *Br J Sports Med.* 2014;48(3):174–7.
43. World Health Organization. Ottawa charter for health promotion. 1986.
44. U.S. Department of Health and Human Services: Healthy People 2030 Framework. <https://www.healthypeople.gov/2020/About-Healthy-People/Development-Healthy-People-2030/Framework>
45. Conroy D, Maher J, Elavsky S, Hyde A, Doerksen S. Sedentary behavior as a daily process regulated by habits and intentions. *Health Psychol.* 2013;32(11):1149–57.
46. Maher JP, Conroy DE. A dual-process model of older adults' sedentary behavior. *Health Psychol.* 2015;
47. Barker RG. *Ecological psychology.* Stanford University Press; 1968.
48. Kazi A, Duncan M, Clemes S, Haslam C. A survey of sitting time among UK employees. *Occup Med.* 2014;64(7):497–502.
49. Leask CF, Harvey JA, Skelton DA, Chastin SF. Exploring the context of sedentary behaviour in older adults (what, where, why, when and with whom). *Eur Rev Aging Phys Act.* 2015;12:4.
50. Neuhaus M, Healy GN, Dunstan DW, Owen N, Eakin EG. Workplace sitting and height-adjustable workstations: a randomized controlled trial. *Am J Prev Med.* 2014;46(1):30–40.
51. Steeves JA, Thompson DL, Bassett DR. Energy cost of stepping in place while watching television commercials. *Med Sci Sports Exerc.* 2012;44:330–5.
52. Sugiyama T, Neuhaus M, Cole R, Giles-Corti B, Owen N. Destination and route attributes associated with adults' walking: a review. *Med Sci Sports Exerc.* 2012;44(7):1275–86.
53. Owen N, Sugiyama T, Koohsari MJ, Debourdeauduij I, Hadgraft N, Oyeyemi A, Aguinaga-Ontoso I, Mitáš J, Troelsen J, Davey R, Schofield G, Cain K, Sarmiento O, Reis R, Salvo D, Macfarlane D, Sallis J, Cerin E. Associations of neighborhood environmental attributes with adults' objectively-assessed sedentary time: IPEN adult multi-country study. *Prev Med.* 2018;115:126–33.
54. Owen N, De Bourdeaudhuij I, Sugiyama T, Leslie E, Cerin E, Van Dyck D, et al. Bicycle use for transport in an Australian and a Belgian city: associations with built-environment attributes. *J Urban Health.* 2010;87(2):189–98.
55. Thorp AA, Healy GN, Winkler E, Clark BK, Gardiner PA, Owen N, et al. Prolonged sedentary time and physical activity in workplace and non-work contexts: a cross-sectional study of office, customer service and call centre employees. *Int J Behav Nutr Phys Act.* 2012;9:128.
56. Parry S, Straker L. The contribution of office work to sedentary behaviour associated risk. *BMC Public Health.* 2013;13(1):296.
57. Healy GN, Eakin EG, Lamontagne AD, Owen N, Winkler EA, Wiesner G, et al. Reducing sitting time in office workers: short-term efficacy of a multicomponent intervention. *Prev Med.* 2013;57(1):43–8.
58. Straker L, Healy GN, Atherton R, Dunstan DW. Excessive occupational sitting is not a “safe system of work”: time for doctors to get chatting with patients. *Med J Aust.* 2014;201(3):138–40.

59. Bale JM, Gazmararian JA, Elon L. Effect of the work environment on using time at work to exercise. *Am J Health Promot.* 2014;29(6):345–52.
60. Burton J, World Health Organization. WHO Healthy workplace framework and model: Background and supporting literature and practices. 2010. http://www.who.int/occupational_health/healthy_workplace_framework.pdf. Accessed 16 Feb 2016.
61. World Health Organization. Healthy workplaces: a model for action: for employers, workers, policy-makers and practitioners. 2010. http://www.who.int/occupational_health/publications/healthy_workplaces_model.pdf. Accessed 16 Feb 2016.
62. Pronk NP. Design recommendations for active workplaces. *Ergon Des.* 2015;23(3):36–40.
63. Hadgraft NT, Lynch BM, Clark BK, Healy GN, Owen N, Dunstan DW. Excessive sitting at work and at home: correlates of occupational sitting and TV viewing time in working adults. *BMC Public Health.* 2015;15(1):899.
64. De Cocker K, Duncan MJ, Short C, van Uffelen JG, Vandelanotte C. Understanding occupational sitting: prevalence, correlates and moderating effects in Australian employees. *Prev Med.* 2014;67:288–94.
65. Wilks S, Mortimer M, Nylen P. The introduction of sit-stand worktables; aspects of attitudes, compliance and satisfaction. *Appl Ergon.* 2006;37(3):359–65.
66. Chau JY, Daley M, Srinivasan A, Dunn S, Bauman AE, van der Ploeg HP. Desk-based workers' perspectives on using sit-stand workstations: a qualitative analysis of the Stand@Work study. *BMC Public Health.* 2014;14:752.
67. Neuhaus M, Eakin EG, Straker L, Owen N, Dunstan DW, Reid N, et al. Reducing occupational sedentary time: a systematic review and meta-analysis of evidence on activity-permissive workstations. *Obes Rev.* 2014;15(10):822–38.
68. Neuhaus M, Healy GN, Fjeldsoe BS, Lawler S, Owen N, Dunstan DW, et al. Iterative development of stand up Australia: a multi-component intervention to reduce workplace sitting. *Int J Behav Nutr Phys Act.* 2014;11:21.
69. Dunstan DW, Wiesner G, Eakin EG, Neuhaus M, Owen N, LaMontagne AD, et al. Reducing office workers' sitting time: rationale and study design for the stand up Victoria cluster randomized trial. *BMC Public Health.* 2013;13:1057.
70. Shrestha N, Ijaz S, Kukkonen-Harjula KT, Kumar S, Nwankwo CP. Workplace interventions for reducing sitting at work. *Cochrane Database Syst Rev.* 2015;1:Cd010912.
71. Tew GA, Posso MC, Arundel CE, McDaid CM. Systematic review: height-adjustable workstations to reduce sedentary behaviour in office-based workers. *Occup Med (Lond).* 2015;
72. Chau JY, van der Ploeg HP, van Uffelen JG, Wong J, Riphagen I, Healy GN, et al. Are workplace interventions to reduce sitting effective? A systematic review. *Prev Med.* 2010;51(5):352–6.
73. Chastin SF, Schwarz U, Skelton DA. Development of a consensus taxonomy of sedentary behaviors (SIT): report of Delphi Round 1. *PloS One.* 2013;8(12):e82313.
74. Sugiyama T, Hadgraft N, Clark BK, Dunstan DW, Chevez A, Healy GN, Cerin E, LaMontagne AD, Shibata A, Oka K, Owen N. Office spatial design attributes, sitting, and face-to-face interactions: systematic review and research agenda. *Build Environ.* 2020;2:107426.
75. Müller AM, Chen B, Wang NX, Whitton C, Direito A, Petrunoff N, Müller-Riemenschneider F. Correlates of sedentary behaviour in Asian adults: a systematic review. *Obes Rev.* 2020;21(4):e12976.
76. Lin CY, Koohsari MJ, Liao Y, Ishii K, Shibata A, Nakaya T, McCormack GR. Hadgraft the physically-active and sedentary behaviour: a systematic review of observational studies. *Int J Behav Nutr Phys Act.* 2020;17(1):1–24.
77. Buck C, Loyen A, Foraita R, Van Cauwenberg J, De Craemer M, Mac Donncha C, Oppert JM, Brug J, Lien N, Cardon G, Pigeot I. Factors influencing sedentary behaviour: a system based analysis using Bayesian networks within DEDIPAC. *PloS One.* 2019;14(1):e0211546.
78. Healy GN, Eakin EG, Owen N, Lamontagne AD, Moodie M, Winkler EA, Fjeldsoe BS, Wiesner G, Willenberg L, Dunstan DW. A cluster randomized controlled trial to reduce office workers' sitting time: impact on activity outcomes. *Med Sci Sports Exerc.* 2016;48(9):1787–97.

79. Pereira MA, Mullane SL, Toledo MJ, Larouche ML, Rydell SA, Vuong B, Feltes LH, Mitchell NR, de Brito JN, Hasanaj K, Carlson NG. Efficacy of the ‘Stand and Move at Work’ multicomponent workplace intervention to reduce sedentary time and improve cardiometabolic risk: a group randomized clinical trial. *Int J Behav Nutr Phys Act.* 2020;17(1):1.
80. Edwardson CL, Biddle SJ, Clarke-Cornwell A, Cledes S, Davies MJ, Dunstan DW, Eborall H, Granat MH, Gray LJ, Healy GN, Richardson G. A three arm cluster randomised controlled trial to test the effectiveness and cost-effectiveness of the SMART Work & Life intervention for reducing daily sitting time in office workers: study protocol. *BMC Public Health.* 2018;18(1):1–3.
81. Blackburn NE, Wilson JJ, McMullan II, et al. The effectiveness and complexity of interventions targeting sedentary behaviour across the lifespan: a systematic review and meta-analysis. *Int J Behav Nutr Phys Act.* 2020;17:53. <https://doi.org/10.1186/s12966-020-00957-0>.
82. Hadgraft NT, Brakenridge CL, Dunstan DW, Owen N, Healy GN, Lawler SP. Perceptions of the acceptability and feasibility of reducing occupational sitting: review and thematic synthesis. *Int J Behav Nutr Phys Act.* 2018;15(1):1–8.
83. Rawlings GH, Williams RK, Clarke DJ, English C, Fitzsimons C, Holloway I, Lawton R, Mead G, Patel A, Forster A. Exploring adults’ experiences of sedentary behaviour and participation in non-workplace interventions designed to reduce sedentary behaviour: a thematic synthesis of qualitative studies. *BMC Public Health.* 2019;19(1):1099. <https://doi.org/10.1186/s12889-019-7365-1>.
84. Landais LL, Damman OC, Schoonmade LJ, Timmermans DR, Verhagen EA, Jelsma JG. Choice architecture interventions to change physical activity and sedentary behavior: a systematic review of effects on intention, behavior and health outcomes during and after intervention. *Int J Behav Nutr Phys Act.* 2020;17(1):1–37.