

## Excessive occupational sitting and mental health in young people: What is the extent of the problem and how can we address it?

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## **Executive summary**

### *Background and rationale*

Due to the rising prevalence of desk-based work, excessive sitting represents an emerging occupational health and safety issue. Employed adults are typically sitting for over 9 hours per day. Spending large periods of the day seated with insufficient active breaks increases the risk of several physical and mental health conditions, including depression and anxiety disorders. Allowing or facilitating excessive sitting in the workplace can affect employees' mental health and compromise the duty of care between an employer and employee. Combatting excessive occupational sitting with regular breaks involving light activity for a couple of minutes every 30 minutes may reduce this risk while also enhancing productivity by promoting cognitive performance and reducing absenteeism and presenteeism. Over time, these productivity improvements will produce economic gains for employers.

Most depression and anxiety disorders first occur during late adolescence and young adulthood, around the same time that many enter the workplace. Focusing on younger employees during this crucial period can produce cumulative long-term benefits for preventing or intervening early on depression and anxiety disorders. While employers are increasingly implementing measures to improve employee mental health, many approaches are not evidence-based. We systematically searched online databases to identify and summarise evidence on the potential risks of excessive occupational sitting, methods of reducing excessive sitting in the workplace or home-working environment, and the changes necessary to tackle this emerging health and safety issue.

### *Findings*

After screening a total of 5,628 systematic reviews, 27 were eligible for inclusion in the full report, containing data from 352 individual studies. From 19 reviews of 252 studies on excessive sitting interventions, we found several evidence-based strategies that can reduce occupational sitting by around an hour per 8-hour workday. They do not compromise work performance and may improve wellbeing, fatigue, cognition, and stress. For example, every hour reduction in daily sitting can decrease depression symptoms by around 10%, and anxiety symptoms by approximately 15%. The most effective strategies included providing dynamic workstations (e.g., sit-stand desks) and behavioural and cultural strategies that support and promote an active working environment. Most of these components are deliverable in home and office settings using digital platforms. Strong organisational support and visible participation of co-workers, managers, and role models are essential to these strategies' success.

While further economic evaluations are necessary, there was some evidence that large-scale interventions provide a substantial return on investment through reduced absenteeism, presenteeism, and increased productivity. However, a paucity of studies included sufficient follow-up periods to examine longer-term impacts on productivity or sustainability. Most studies also focussed on improving physical health and lacked

sufficient measures of mental health. Few studies specifically targeted interventions at young people. But the principles and findings of these studies remain applicable to young people as the relationships between sitting, movement, and mental health are consistent across different age groups.

#### *Conclusions and next steps*

There is an urgent need for evidence-based methods of safeguarding employees' mental health, particularly in younger employees. Overwhelming evidence suggests that excessive sitting increases employees' physical and mental health risks, but it is modifiable. Future research must continue to evaluate the longer-term impact of interventions for reducing occupational sitting on cost-effectiveness and mental health. Employers already provide routine display screen equipment and workstation assessments and adjustments as part of their duty of care to employees. However, these typically focus on preventing musculoskeletal and visual problems or stress.

Policymakers and employers should include excessive sitting as a principal risk factor associated with desk-based work to ensure the provision of control measures that protect mental health. Employers and employees must work together to design working routines that encourage regular breaks for movement or posture changes that prevent excessive sitting. Coordinated actions from policymakers, employers, and employees will be necessary to produce sustainable reductions in excessive occupational sitting, protect employee wellbeing, and enhance productivity.

## 1. Introduction

Depression and anxiety disorders represent a widespread public health concern. Depression is the first, and anxiety disorders are the sixth leading cause of global disability (1). Depression and anxiety often co-occur. Symptoms vary from person to person but can include persistent low mood, feelings of hopelessness, poor concentration, fatigue, feelings of dread or panic, irritability, loss of motivation, and sleep and appetite changes. Together, these common mental disorders cost the global economy an estimated \$1.15 trillion per year through loss in productivity and labour force participation (2). These costs are further compounded by the long-term physical health complications associated with depression and anxiety disorders, such as the increased risk of cardiovascular and metabolic diseases (e.g., diabetes) (3). The substantial impact that depression and anxiety can have across the lifespan limit the participation, enjoyment, and contributions of people in the workplace.

Depression and anxiety disorders typically first occur during adolescence and young adulthood (4,5). Strategies for preventing or intervening early in young people can mitigate the substantial, long-term burden of these disorders on individuals and workplaces. Spending large proportions of the day sitting increases the risk of several chronic physical and mental health conditions (6), including depression and anxiety disorders (7,8). Prolonged bouts of uninterrupted sitting are particularly hazardous. We refer to these behaviours as excessive sitting in this report. Desk-based occupations are a major contributor to total daily sitting (9), which typically includes prolonged and uninterrupted bouts of sitting. International governing bodies have increasingly recognised excessive sitting as an occupational health and safety issue that compromises an employer's duty of care and requires direct intervention, such as a recent Safe Work Australia report (10).

The rising burden and impact of depression and anxiety in young people and the commonality of excessive occupational sitting create a pressing need to identify practical solutions to these problems. This report outlines the evidence that reducing excessive occupational sitting can lower and prevent depression and anxiety symptoms in young people with primarily desk-based jobs. Where possible, we identified studies from young people (under the age of 25) but also draw relevant evidence from people of different age groups. We aim to:

- 1) summarise the evidence that excessive occupational sitting time increases the risk or severity of depression and anxiety disorders in people with primarily desk-based jobs, which harms productivity
- 2) identify evidence-based methods of reducing excessive sitting time, including prolonged and uninterrupted sitting, in the workplace or home-working environments
- 3) provide guidance and recommendations for policymakers, employers, and employees to combat excessive occupational sitting and protect the mental health and productivity of employees, with an emphasis on those under the age of 25

## 2. Methodology

We performed systematic searches of online peer-reviewed databases to identify and evaluate evidence from systematic reviews relevant to our aims. To address aim 1, we used search terms outlined in the Supplementary Materials (page 2) to identify systematic reviews on the relationship between sitting or sedentary behaviour and mental health or cognitive outcomes. For aim 2, we used different search terms (Supplementary Materials page 5) to identify methods of reducing sitting or sedentary behaviour or increasing light activity during work, including remote working. For both searches, we included studies of varying designs in working-age participants. Further details on these methods are available in the Supplementary Materials. We summarised the results of included reviews in Tables 1 to 3 (Appendices).

### **3. Why is excessive occupational sitting a problem?**

Sedentary behaviour refers to any activity in a sitting, lying, or reclining position with low energy expenditure (11), such as using a computer while seated. Over the last few decades, the growth of desk-based occupations has been a major contributor to rising sedentary behaviour levels. Employed adults spend around 9.4 hours sedentary per day, with office employees accumulating 66% of this time at work (9). Spending large proportions of the day sedentary is associated with a higher risk of several chronic diseases and early death (6). A meta-analysis of data from over 1 million people found that meeting national physical activity guidelines was insufficient to mitigate the elevated risk of early death associated with spending over 8 hours sedentary per day (12). Standing more during the day can lower the risk of early death (13), and additional increases in daily movement can produce even greater benefits (14).

Excessive sitting also increases the risk of depression and anxiety disorders and related problems, such as elevated stress and lower cognitive performance. We systematically searched online databases to identify and summarise this evidence in section 3.1., following search protocols in the Supplementary Materials (pages 1 to 3).

#### **3.1. Sitting time, mental health, and related problems at work**

We screened 2,327 systematic reviews and identified 8 that met our eligibility criteria, which included 167 studies. We found evidence that high sedentary behaviour is associated with an increased risk of depression, anxiety disorders, and lower cognitive performance and quality of life (see Table, Appendix). For example, a 2020 meta-analysis of 12 prospective studies found that high sedentary behaviour was associated with an approximate 10% increased risk of depression (7). A 2019 meta-analysis of 13 studies with mixed designs found that high sedentary behaviour was associated with around 1.48 times higher odds of an anxiety disorder (8). Both reviews included a wide range of definitions for high sedentary behaviour, including  $\geq 2$  to  $\geq 8$  hours per day of screen or sitting time. A trial that experimentally induced an average of just 32 additional minutes

of daily sedentary behaviour in healthy young adults for two weeks led to increased mood disturbances and psychological distress, independently of physical activity (15).

Excessive sitting increases the risk of depression and anxiety disorders. The strength of this evidence indicates that employers may risk compromising their duty of care to employees by overlooking excessive sitting as a risk factor for mental health disorders in the workplace. These disorders also reduce labour force participation and affect productivity through absence from work (absenteeism) or working at a reduced capacity (presenteeism) (2). Over time, this reduction in productivity will translate into fewer economic gains for employers.

Excessive sitting can influence mental health through multiple psychological, social, and biological mechanisms (16) that might also directly limit cognitive performance, further compounding the risk of presenteeism. For example, it may affect functioning in the hippocampal brain region, potentially leading to further problems, such as poorer memory performance or stress regulation (17). A 2017 systematic review of six studies found that high sedentary behaviour was associated with poorer cognitive performance, including memory, executive functioning, and global cognitive functioning (18). However, both reviews indicated that more work was necessary to clearly outline the possible implications of excessive sitting on cognitive performance over time (18,19). Recent trials have found that breaking up prolonged bouts of sitting with light physical activity improved working memory, executive functioning, and fatigue (20,21). Light activities are low-intensity behaviours that typically require standing up and moving, such as walking around the office at a comfortable pace or making a cup of tea. Regularly interrupting bouts of sitting every 30 minutes for 2 to 3 minutes using light activities stimulate adaptive brain changes, such as increases in blood flow, which may improve psychological wellbeing and cerebrovascular health (22–24).

### **3.2. Reducing and interrupting sitting at work with light physical activity**

Several meta-analyses have found that physical activity interventions reduce existing depression and anxiety symptoms (25,26). Higher physical activity levels in people without symptoms also reduce their future risk of depression and anxiety disorders (27,28). Most studies focus on moderate-to-vigorous intensity activities, such as running or cycling. However, interventions for increasing moderate-to-vigorous activity in the workplace have produced mixed results (29). Moderate-to-vigorous activities are effortful and may be impractical to incorporate into the workday. For example, they can require a change of clothes, provision of shower facilities or leaving the office for sufficient space to perform activities.

Light intensity activities may be more suitable for workplace interventions and still beneficial for depression and anxiety disorders (25,26,30). For example, a large randomised controlled trial (RCT) in 620 adults with depression compared light, moderate, and vigorous activity interventions and found that light activity was most effective for maintaining lower depressive symptoms after 12-months (31). Light intensity activities are more manageable and likely to be less disruptive to daily routines. The lower intensity activity can be

sustainable for long enough periods to substantially reduce total sitting time at work, such as through periods of standing at a desk. Light activity is also more suitable for routinely breaking up prolonged periods of sitting at work, such as frequent movement breaks with stretching or gentle movements around the office.

Incorporating light activity into the working day will reduce excessive sitting and its associated risks. It may also lessen the severity of depression and anxiety symptoms in people who already have them. Previous work has produced mixed results when focusing on simultaneously reducing sitting and increasing physical activity in the workplace (32,33). We focus on reducing sitting rather than explicitly increasing physical activity in this report. Given the almost exact inverse correlation between sedentary behaviour and light physical activity (34), workplace interventions targeting sitting will inherently lead to increases in light activity, including standing (35).

### Summary points

- Working-aged adults commonly accumulate most of their daily sedentary time from occupational sitting.
- High levels of sedentary behaviour increase the risk of depression and anxiety disorders and may affect cognitive and work performance. Employers who fail to act against excessive sitting and its associated risks may compromise their duty of care to employees.
- High levels of sedentary behaviour and depression and anxiety disorders also increase the risk of chronic metabolic and cardiovascular diseases. Addressing both risk factors in younger employees can offset the additional long-term absenteeism costs due to chronic physical illness and multimorbidity.
- Participation in light intensity activities can reduce depression and anxiety symptoms and be a practical and sustainable method of reducing daily sitting time.
- Interventions for interrupting bouts of sitting and reducing total sitting time with light activity can improve employees' mental health, cognitive performance, and brain health. For example, just 2 to 3 minutes of light activity every 30 minutes can be beneficial. Addressing these problems can improve productivity through greater labour force participation and lower absenteeism and presenteeism.

## 4. What works for reducing excessive occupational sitting?

We provide an overview of interventions for reducing excessive sitting in the workplace (Section 4.1.) and digital interventions suitable for home-working environments (Section 4.2.) following systematic search protocols outlined in the Supplementary Materials (pages 4 to 6). We screened 3,301 systematic reviews and identified 19 for inclusion in this section, which included 252 individual studies. We use the terms sitting and sedentary time interchangeably throughout this section, depending on how the studies define their outcomes. We also highlight possible barriers to implementing these sitting interventions at work and potential strategies

to overcome them in Section 4.3. Few studies explicitly focus on a specific age group, but the associations between sedentary behaviour and depression and anxiety symptoms are similar in magnitude across younger and older age groups (7,8,30,36). Interventions to increase physical activity also effectively reduce depressive and anxiety symptoms across different age groups (25,26). The consistency of these relationships across age groups indicates that the principles and findings of studies that include people of various ages remain applicable to young people.

#### **4.1. Interventions for reducing excessive sitting time in the workplace**

We identified 14 systematic reviews of 167 studies with interventions to reduce excessive sitting in the workplace (Table 2, Appendix). There are multiple influences on workplace behaviour that interventions typically target, including cultural, environmental, and individual influences. All reviews concluded that the interventions effectively reduced occupational sedentary behaviour, except one that focused exclusively on behavioural interventions, such as goal-setting or self-monitoring (37). Many interventions reported reductions in sedentary behaviour of greater than 60 minutes per 8-hour workday. Few studies reported on how effectively the interventions broke up prolonged bouts of sitting. Most studies included office-employees between the ages of 30 to 60 from various industries, such as university or healthcare staff. All studies were conducted in high-income countries, such as the United Kingdom, Western Europe, the United States, and Australia. Intervention types included environmental (e.g., sit-stand or treadmill desks), behavioural (e.g., goal-setting or self-monitoring), cultural (e.g., frequent movement break policies), or multicomponent (e.g., sit-stand desks with screen-prompts). Study durations were mostly less than 3 months, with some lasting around a year.

Most interventions used dynamic workstations, an individual-level environmental strategy that includes sit-stand, treadmill, or under-desk pedalling. Studies consistently found that dynamic workstations effectively reduced sedentary behaviour time by between 20 to 100 minutes per 8-hour workday. Multicomponent approaches that combine dynamic workstations with other strategies to raise awareness and create cultural shifts around sitting typically produced larger reductions in sitting. Dynamic workstation interventions were typically most effective within the first two weeks (38). Treadmill desks and under-desk pedalling produced larger increases in physical activity or energy expenditure (39–42), but sit-stand desks were more effective for reducing total sitting (32,43).

Some studies found that dynamic workstations, particularly treadmill desks, could affect workplace performance on specific computer-related tasks during a short period of adapting to the new workstation, such as mouse or typing speed (38,40,41,44). However, these findings were inconsistent, and some studies found that dynamic workstations reduced stress and boredom and increased energy, focus, productivity, and wellbeing without affecting cognitive performance (38,40,41,43,44). Other systematic reviews specifically assessing workplace performance have found no impact of sit-stand desks and mixed evidence for initial

declines in computer-based task performance from treadmill desks or under-desk pedalling, which may improve over time (45–49). The long-term benefits of reducing sedentary behaviour and disrupting prolonged bouts of sitting on cognitive performance and fatigue (18,20,21) likely outweigh any short-term disruptions to computer-related task performance.

Interventions without environmental components typically produced smaller reductions in occupational sitting (38). There was mixed evidence for behavioural interventions (32,37,39). These are interventions that usually target individual motivation and volition, such as personalised goal-setting and feedback via screen-prompts. Behavioural interventions generally reduced workplace sedentary behaviour time by 15 to 30 minutes (35,42,50). There was some evidence of larger reductions in sedentary behaviour time in longer studies of 3 to 12 months for behaviour interventions, such as computer prompts (32). Behavioural interventions typically aim to establish sitting less as a habit, which may take several months to employees to adopt.

Few interventions included cultural or policy changes to the workplace, such as standing and walking meetings, frequent standing breaks, or not eating at the desk policies. Workplace policies that encourage short breaks of 1 to 2 minutes every 30 minutes also reduced occupational sitting by around 40 minutes per day compared with two 15-minute breaks per day (32). Environmental interventions that include cultural changes with strong organisational support were generally more effective than single-component intervention (38). Multicomponent interventions reduced occupational sitting by around 60 to 90 minutes, but comparisons were difficult due to large differences between each approach (32,42,50,51). Some evidence suggested that multicomponent interventions were the most effective for reducing occupational sitting (50). Other reviews indicated that environmental interventions alone were slightly more effective, but these studies focused on total rather than occupational sitting (35).

Multicomponent interventions that combine dynamic workstations with behavioural approaches (e.g., screen-prompts and self-monitoring) effectively reduce occupational sitting (35,50,52). Recent multicomponent interventions also target cultural and policy changes through consultations with senior management and other organisational staff to develop and support interventions (53,54). For example, a cluster-RCT of the multicomponent Stand More at Work (SMaRT) intervention provided 77 employees in 19 office clusters with sit-stand desks, seminars, goal setting, self-monitoring, feedback, and coaching sessions (54). The intervention reduced occupational sitting by around 50 minutes per workday at 3 months and over 80 minutes after 12 months compared to a usual practice control group. The intervention also reduced prolonged sitting time, daily anxiety, presenteeism, fatigue, and improved job performance.

The Stand Up Victoria study is another 12-month cluster-RCT of a multicomponent intervention in 231 office-based employees across 14 sites, using a similar combination of environmental, cultural, and behavioural approaches, including sit-stand desks (53). The intervention also appointed team champions to act as role models who promote organisational strategies to sit less, typically via periodic emails to their teams. The intervention led to an approximate 100 minute per workday reduction in sitting at three months and 45 minutes per workday reduction after 12 months, including fewer prolonged bouts of sitting per day. These

multicomponent interventions were feasible, acceptable to employees, practical for delivery at scale, and cost-effective (53–57). For example, the SMArT intervention led to a return on investment of 256% over 12 months from increased productivity (56). Stimulating cultural changes with strong organisational support is a promising method of ensuring that these interventions lead to sustainable and widespread reductions in excessive occupational sitting (38).

While only a few studies directly assessed the impact of these interventions on mental health, such as the SMArT intervention, the magnitude of change in sitting that they produce can have a meaningful impact on employees' mental health. For example, every hour decrease in daily sedentary behaviour could reduce depression symptoms by approximately 10% (30) and anxiety symptoms by around 15% (36) in the general population. Reductions of this size at the population level are sufficient to prevent mild symptoms from developing in individuals or reduce the risk of existing symptoms worsening and leading to clinical diagnoses. These reductions are of similar magnitude to the substantial physical health benefits of reduced sitting. For example, increasing daily light activity by one hour could lead to a 14% reduction in the risk of coronary heart disease (58). Increasing an employee's daily light activity from 200 to 275 minutes per day could reduce their risk of an early death by approximately 42% (14).

Some challenges for future research include determining the optimal design of interventions for reducing occupational sitting in different settings, as other recent multicomponent trials have been less effective (59). Most research focuses on adapting the desk as a central environmental workplace change, but other strategies could target different aspects of the environment, such as chairs or workplace layouts. We also lack cost-effectiveness data (60), particularly in the longer-term, where the financial gains likely accumulate from reductions in absenteeism and presenteeism. While data on the long-term sustainability of these interventions is lacking, trials are underway to examine their effectiveness over 24-months, including for depression and anxiety-related outcomes (61). The paucity of studies that directly assess the impact of these interventions of mental health is another area of focus for future research. Other trials are also incorporating incentive structures to motivate long-term reductions in workplace sitting, such as financial or food-based rewards for activity (62).

Interventions have successfully replaced sitting with standing, but the benefits are likely to be more pronounced with light lower body movement while standing, such as gentle calf raises or squats. Approaches for integrating dynamic standing and light activity are adaptable to different working environments and tasks. For example, employees may benefit from standing to organise documents or walking during a phone call. These activities could be particularly beneficial at certain times of the day, such as combatting post-prandial fatigue. Some workplaces may allow the flexibility to organise daily tasks into patterns that frequently break up sitting, such as spreading meetings, phone calls, or printing tasks throughout the day. A few minutes of light activity before mentally demanding tasks could provide brain and cognitive benefits (20–24) that improve performance. Optimal strategies for combating excessive sitting should be adaptable and will vary across workplaces, tasks, and employees.

### Summary points

- Several approaches led to meaningful reductions in occupational sitting of over an hour per 8-hour workday. Increasing daily light activity by just one hour could reduce depression symptoms by around 10% and anxiety symptoms by 15%, and produce substantial physical health benefits.
- Dynamic workstations are central to many strategies for reducing occupational sitting and do not negatively affect job performance.
- Behavioural approaches aiming for habit formation may require a period of adjustment and are most beneficial when combined with dynamic workstations, which tend to produce more immediate reductions in sitting.
- Multicomponent interventions that combine dynamic workstations with behavioural and cultural changes are a cost-effective method of reducing occupational sitting, with improved employee wellbeing and a return on investment through greater productivity.
- Strong organisational support and leadership are essential components for creating sustainable workplace change.
- There is currently a paucity of data to assess the long-term impact of these interventions or with direct measures of depression or anxiety symptoms. However, studies with longer evaluation periods are underway to assess the long-term sustainability of multicomponent interventions, their cost-effectiveness, and their potential impact on mental health.
- The best methods for incorporating dynamic standing or light activity into the workday are adaptable and will vary across workplaces, tasks, and employees.

### 4.2. Digital interventions for reducing excessive sitting while working from home

We identified five systematic reviews of 101 studies with three meta-analyses of studies using digital interventions to target sedentary behaviour that could be suitable for reducing excessive sitting while working from home (Table 3, Appendix). We found some evidence that digital interventions can reduce sitting time by around 30 to 50 minutes per day. However, the effect sizes tended to be smaller and less consistent than the workplace interventions. Participants in these studies were typically adults in high-income countries. Most interventions delivered interventions through mobile phone applications, computers (e.g., emails or websites), or wearable activity trackers. These tools are suitable for home-working environments and offer a platform to monitor activity, provide prompts, and feedback on activity.

Most interventions involved other components to support behaviour change, such as group education sessions or individual counselling (63,64). Some used passive (e.g., pedometers or accelerometers) or active (e.g., electronic logbooks) measures to influence daily sitting time through a self-monitoring framework (65). These

interventions could reduce daily sitting time, but all self-monitoring approaches were delivered within multicomponent frameworks that may have contributed to these positive findings. Other interventions using a variety of mHealth technologies designed for health promotion led to small reductions in daily sedentary behaviour and increases in walking (66).

Digital interventions could reduce excessive sitting, but such approaches are still relatively novel (67). Robust trials with longer-term follow-up periods are necessary to clarify these approaches' effectiveness for reducing sitting. However, digital interventions are an increasingly common and effective method of reducing depression and anxiety symptoms (68). For example, many smartphone applications exist for delivering psychotherapy or tracking and providing feedback on mental health symptoms or general metrics of wellbeing, such as stress or sleep. Digital approaches for targeting excessive sitting could also incorporate these features that are tailored to support mental health. There is some evidence that standalone digital interventions can reduce sedentary behaviour and depression and anxiety symptoms in the workplace (69,70). For example, a 3-week pilot study recently found that a nudge-based digital intervention targeting occupational sedentary behaviour reduced stress and depression and anxiety symptoms (71). Although the pilot did not find evidence of changes in sedentary behaviour, adapting these digital interventions for home-working environments may prove useful in larger-scale trials.

Several effective multicomponent studies also deliver parts of their intervention digitally, including the SMART and Stand Up Victoria trials. Adapting interventions with established effectiveness and acceptability for home-working environments is possible through online platforms. For example, video conferencing programmes are useful for delivering information or social and organisational support, and software is available to facilitate digital logs and provide tailored feedback (67). Increased investment in these approaches may yield greater reductions in sitting while home-working, such as providing table-top converters for height-adjustable desks at home or activity monitoring devices. A national implementation trial is currently underway in Australia for the BeUpstanding programme, an online adaptation of the Stand Up Victoria programme (72). It provides online training and resources for workplace champions to deliver a tailored 8-week intervention within their work team to reduce sitting and increase activity.

### **Summary points**

- Early evidence suggests that digital interventions are effective for reducing excessive sitting. But robust, longer-term trials are necessary to clearly outline the effectiveness of these novel approaches to reducing sitting.
- Mobile phones, computers, and wearables are suitable platforms for delivering interventions to home-working environments.
- Many aspects of existing multicomponent interventions are adaptable to online platforms, such as delivering seminars through video conferencing software.

- Digital interventions are also effective in reducing depression and anxiety symptoms. Digital approaches to reducing excessive sitting while working from home could also include components that are tailored to prevent or reduce depression or anxiety symptoms.

### **4.3. Barriers and facilitators**

Various factors can reduce (barriers) or increase (facilitators) the likelihood of successfully implementing interventions that produce sustainable reductions in excessive occupational sitting time. A recent systematic review of 32 qualitative studies identified various individual, work-related, cultural, or environmental barriers and facilitators to reducing occupational sitting (73). Many key barriers were work-related factors, such as employees having insufficient tasks that allow for leaving the desk and excessive work or time pressures that prohibit interruptions for standing or moving around the office. Cultural factors were also identified as potential barriers. For example, some employees were concerned about perceptions of standing or moving as unusual by colleagues or unproductive by managers. Some individual barriers included forgetting to change posture, being unaware of time spent sitting, or lacking guidance.

Key facilitators included social and organisational support for sitting less, such as high co-employee and manager involvement and encouragement. Visible participation of managers or role models can have a strong influence on the acceptability of a dynamic work environment. Individual motivation, awareness of sitting time, improvements in productivity and concentration, and sitting less becoming a habit were examples of individual-level facilitators.

The types of barriers and facilitators will vary across different workplaces and populations. For example, one study found that employees from organisations of various sizes consistently report similar individual-level barriers and facilitators, such as forming habits and routines (74). In contrast, cultural and work-related factors varied between different organisations. For example, the perception of sitting at a desk as a requirement for productivity was a barrier in charities and local authorities, but not for small businesses or large corporations. Studies of workplaces using sit-stand desks for several years suggest that an introductory phase can improve familiarity and provide immediate benefits for concentration that enable longer-term use (75). Barriers can also vary in different contexts. For example, a recent study in university employees found that people were uncomfortable about standing during a normally-seated meeting, but felt a sense of power and control while standing to lead a meeting (76).

Understanding and responding to the experiences of employees across the organisation is essential to the sustainability of occupational sitting interventions, particularly in the early stages. Adherence and acceptability of these interventions will vary across individuals, workplaces, and industries. Employers implementing these interventions should be adaptable and more research in diverse settings would be beneficial to tailor these strategies.

### Summary points

- Creating a work environment that supports and encourages less sitting at all levels of the organisation is essential for effective interventions, particularly visible participation from managers or role models.
- The perception of standing or moving during work being unproductive or unusual is a significant barrier that should be addressed in interventions.
- Monitoring and adapting to feedback on barriers and facilitators to reducing sitting can improve adherence to interventions, particularly in its early stages.

### 5. What can employees, employers, and policymakers do to reduce sitting at work?

Sitting has become ingrained in modern society and typically accounts for a large proportion of the day. The recent COVID-19 pandemic could further increase excessive sitting through a rise in remote working and lockdown restrictions, such as gym and leisure centre closures (77). Workplace designs and routines are major contributors to excessive sitting for many people. There is comprehensive evidence that sedentary time increases the risks of several physical and mental health conditions that make excessive occupational sitting a modifiable health and safety concern. Interventions can effectively reduce occupational sitting and create healthier working environments. Employers failing to prevent excessive occupational sitting and its associated risks could compromise their duty of care to safeguard employees' wellbeing.

Stimulating changes to working practices that address excessive sitting will require collective action from policymakers, employers, and employees. For example, the UK's Health and Safety Executive Regulations for Display Screen Equipment already identifies principal risk factors associated with desk-based work to include musculoskeletal, postural, or visual problems, and fatigue or stress. The regulations require employers to perform suitable and sufficient assessments of workstations and provide reasonable adjustments for the principal risk factors, which should be amended to include excessive sitting. Based on the findings of this report, our recommendations are below.

#### Policymakers

- There is overwhelming evidence that high volumes of total sitting and prolonged, uninterrupted bouts of sitting are a health and safety concern that requires explicit regulatory action to protect employees' mental health.
- Existing legislation on Display Screen Equipment Regulations should be updated to ensure that excessive sitting and the associated mental health issues are considered a principal risk factor of their use. Guidance on potential control measures to reduce these risks should include:

- A requirement that employers are to ensure employees in occupations involving excessive sitting have the autonomy and are encouraged to make regular changes in posture, such as with the provision of dynamic workstations. In workplaces where dynamic workstations are infeasible, regulators should provide sufficient guidance on cultural, policy, and behavioural strategies for reducing excessive sitting to ensure that these approaches are suitable for settings with fewer available resources.
- Mandatory employer Display Screen Equipment training for users or operators should include guidance on the dangers of occupational sitting and the importance of regular active interruptions to prolonged sitting. Highlighting the mental health risks of excessive sitting may send a more salient message to young workers, where depression and anxiety disorders are highly prevalent.
- Health and Safety Executive regulators should recognise excessive sitting as part of the 'suitable and sufficient' analysis of workstations.
- Government bodies should more widely promote initiatives that allow employees to incorporate regular activity into their routines, such as flexible working practices that allow for more activity breaks or cycle to work schemes.
- Reducing excessive sitting in employees under 25 years old should be a target for policies aiming to prevent or reduce depression and anxiety disorders. Targeting young employees will also reduce the long-term risks of chronic physical conditions, such as cardiovascular disease. The benefits of this strategy will accumulate over time.

### **Employers**

- Investing in strategies to reduce total and prolonged bouts of sitting during work can produce immediate and long-term reductions in the risk of depression and anxiety. These changes will support employers to fulfil their duty of care to employees and increase workplace productivity leading to long-term economic gains.
- Employers should consider the risks associated with excessive occupational sitting when conducting Display Screen Equipment workstation assessments and implement effective control measures to reduce those risks to a reasonably low level. For example:
  - Employers should aim for approaches that initially replace at least one hour of occupational sitting time with light activity, expecting greater reductions over time. Highlighting the importance of these strategies for protecting mental health may send a more relatable message to incite behaviour change in young employees given the prevalence of mental health problems relative to some physical problems associated with excessive sitting in this population.
  - Employers should also aim to break up prolonged bouts of sitting with frequent movement breaks. Where possible, employers should encourage regular active breaks for one to three minutes every 30 minutes. Display Screen Equipment Regulation 4 already highlights the

importance of taking breaks away from workstations. Human resources and occupational health departments should encourage similar movement breaks from sitting at a desk to safeguard employees' mental health and improve job performance by providing benefits for the brain and cognitive function.

- Employers should consider allocating resources to dynamic workstations as a central component to reducing sitting, where possible. Effective strategies must also include behavioural components that target individual employee motivation and cultural and organisational support components to create a dynamic work environment where sitting less and moving more is the norm.
- Employers should consider the excessive sitting as part of a 'suitable and sufficient' analysis that Health and Safety Executive regulations already require.
- Financial investments alone may be insufficient to produce lasting changes in excessive sitting. Employers should develop interventions with strong organisational support, including visible participation and encouragement from management, team leaders, and role models.
- Organisations with fewer resources should consider combining lower cost behavioural and cultural approaches, such as incorporating movement breaks into routines with email-based reminders. Well-established methods to improve focus and productivity are adaptable to include movement breaks, such as the Pomodoro technique. Where possible, organise tasks in patterns that provide ample opportunities to sit less and break up long seated tasks.
- Employers that endorse home-working practices should consider digital platforms, ideally as part of a multicomponent approach. Digital interventions can deliver behavioural and cultural components of interventions to reduce sitting while working at home.
- The effectiveness and feasibility of interventions will vary across different environments. Early monitoring of employee experiences and adapting to feedback will be essential for workplaces tailoring approaches to produce sustainable reductions in sitting across different settings.

### **Employees**

- Social norms that discourage standing or moving while working are a barrier to successfully reducing occupational sitting. Individual employees can support each other by visibly participating in interventions to create a healthy and dynamic work environment.
- People who are highly sedentary may experience muscle stiffness and fatigue from the lack of daily activity. The shift to increased standing and movement may cause some initial discomfort. However, such fatigue and muscle problem issues will subside over time. Highly sedentary employees may benefit from starting with smaller reductions in sitting of 20 to 40 minutes per day and gradually increasing activity.
- Employees should raise awareness about the dangers of excessive sitting for mental and physical health with management and employee representatives. Unhealthy sitting behaviours are an occupational hazard that employers must address to safeguard employees' health and wellbeing.

- Some employees can take leadership to drive changes in harmful work routines, such as suggesting walking meetings, taking movement breaks from sitting to visit a colleague or make a drink, and avoiding sitting in common areas during lunch breaks.
- In job roles that allow flexibility, employees should consider organising tasks that can involve standing or moving to interrupt bouts of sitting. For example, scheduling standing meetings, walking phone calls, or trips to the printer or storeroom at least once an hour.
- Where possible, employees should consider active travel to work several times per week and take advantage of relevant schemes, such as cycle to work schemes.

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**Conflicts of interest**

No authors have any conflicts of interest to declare.

## References

1. World Health Organisation. Depression and Other Common Mental Disorders Global Health Estimates [Internet]. Geneva; 2017.
2. Chisholm D, Sweeny K, Sheehan P, Rasmussen B, Smit F, Cuijpers P, et al. Scaling-up treatment of depression and anxiety: a global return on investment analysis. *The Lancet Psychiatry* [Internet]. 2016 May 1;3(5):415–24.
3. Firth J, Siddiqi N, Koyanagi A, Siskind D, Rosenbaum S, Galletly C, et al. The Lancet Psychiatry Commission: a blueprint for protecting physical health in people with mental illness. *The Lancet Psychiatry* [Internet]. 2019 Aug 1;6(8):675–712.
4. Patton GC, Coffey C, Romaniuk H, Mackinnon A, Carlin JB, Degenhardt L, et al. The prognosis of common mental disorders in adolescents: A 14-year prospective cohort study. *Lancet*. 2014;383(9926):1404–11.
5. Thapar A, Collishaw S, Pine DS, Thapar AK. Depression in adolescence. Vol. 379, *The Lancet*. Lancet Publishing Group; 2012. p. 1056–67.
6. Biswas A, Oh PI, Faulkner GE, Bajaj RR, Silver MA, Mitchell MS, et al. Sedentary Time and Its Association With Risk for Disease Incidence, Mortality, and Hospitalization in Adults. *Ann Intern Med* [Internet]. 2015 Jan 20;162(2):123.
7. Huang Y, Li L, Gan Y, Wang C, Jiang H, Cao S, et al. Sedentary behaviors and risk of depression: a meta-analysis of prospective studies. Vol. 10, *Translational Psychiatry*. Springer Nature; 2020. p. 1–10.
8. Allen MS, Walter EE, Swann C. Sedentary behaviour and risk of anxiety: A systematic review and meta-analysis. *J Affect Disord* [Internet]. 2019 Jan 1;242:5–13.
9. Prince SA, Elliott CG, Scott K, Visintini S, Reed JL. Device-measured physical activity, sedentary behaviour and cardiometabolic health and fitness across occupational groups: A systematic review and meta-analysis. *Int J Behav Nutr Phys Act*. 2019;16(1):1–15.
10. Straker L, Dunstan D, Gilson N, Healy G. Sedentary work. Evidence on an emergent work health and safety issue. 2016;
11. Tremblay MS, Aubert S, Barnes JD, Saunders TJ, Carson V, Latimer-Cheung AE, et al. Sedentary Behavior Research Network (SBRN) – Terminology Consensus Project process and outcome. *Int J Behav Nutr Phys Act* [Internet]. 2017 Dec 10;14(1):75.
12. Ekelund U, Steene-Johannessen J, Brown WJ, Fagerland MW, Owen N, Powell KE, et al. Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis of data from more than 1 million men and women. *Lancet* [Internet]. 2016 Sep;388(10051):1302–10.

13. Jain P, Bellettiere J, Glass N, LaMonte MJ, Di C, Wild RA, et al. The Relationship of Accelerometer-Assessed Standing Time With and Without Ambulation and Mortality: The WHI OPACH Study. *Journals Gerontol Ser A* [Internet].
14. Ekelund U, Tarp J, Steene-Johannessen J, Hansen BH, Jefferis B, Fagerland MW, et al. Dose-response associations between accelerometry measured physical activity and sedentary time and all cause mortality: systematic review and harmonised meta-analysis. *BMJ* [Internet]. 2019 Aug 21;366:l4570.
15. Endrighi R, Steptoe A, Hamer M. The effect of experimentally induced sedentariness on mood and psychobiological responses to mental stress. *Br J Psychiatry* [Internet]. 2016 Mar 1;208(3):245–51.
16. Kandola A, Ashdown-Franks G, Hendrikse J, Sabiston CM, Stubbs B. Physical activity and depression: Towards understanding the antidepressant mechanisms of physical activity. *Neurosci Biobehav Rev* [Internet]. 2019 Oct 2;
17. Kandola A, Hendrikse J, Lucassen PJ, Yücel M. Aerobic Exercise as a Tool to Improve Hippocampal Plasticity and Function in Humans: Practical Implications for Mental Health Treatment. *Front Hum Neurosci* [Internet]. 2016 Jul 29;10:373.
18. Falck RS, Davis JC, Liu-Ambrose T. What is the association between sedentary behaviour and cognitive function? A systematic review [Internet]. Vol. 51, *British Journal of Sports Medicine*. BMJ Publishing Group; 2017. p. 800–11.
19. Loprinzi P. The effects of sedentary behavior on memory and markers of memory function: a systematic review. *Phys Sportsmed* [Internet]. 2019;47(4):387–94.
20. Wennberg P, Boraxbekk CJ, Wheeler M, Howard B, Dempsey PC, Lambert G, et al. Acute effects of breaking up prolonged sitting on fatigue and cognition: A pilot study. *BMJ Open* [Internet]. 2016 Feb 1;6(2):e009630.
21. Wheeler MJ, Green DJ, Ellis KA, Cerin E, Heinonen I, Naylor LH, et al. Distinct effects of acute exercise and breaks in sitting on working memory and executive function in older adults: A three-arm, randomised cross-over trial to evaluate the effects of exercise with and without breaks in sitting on cognition. *Br J Sports Med* [Internet]. 2020 Jul 1;54(13):776–81.
22. Carter SE, Draijer R, Holder SM, Brown L, Thijssen DHJ, Hopkins ND. Regular walking breaks prevent the decline in cerebral blood flow associated with prolonged sitting. *J Appl Physiol* [Internet]. 2018 Sep 1;125(3):790–8.
23. Bojsen-Møller E, Ekblom MM, Tarassova O, Dunstan DW, Ekblom O. The effect of breaking up prolonged sitting on paired associative stimulation-induced plasticity. *Exp Brain Res* [Internet]. 2020;238(11).
24. Wheeler MJ, Dunstan DW, Smith B, Smith KJ, Scheer A, Lewis J, et al. Morning exercise mitigates the

- impact of prolonged sitting on cerebral blood flow in older adults. *J Appl Physiol* [Internet]. 2019;126(4):1049–55.
25. Stubbs B, Vancampfort D, Rosenbaum S, Firth J, Cosco T, Veronese N, et al. An examination of the anxiolytic effects of exercise for people with anxiety and stress-related disorders: A meta-analysis. *Psychiatry Res* [Internet]. 2017;249:102–8.
  26. Stubbs B, Vancampfort D, Rosenbaum S, Ward PB, Richards J, Soundy A, et al. Dropout from exercise randomized controlled trials among people with depression: A meta-analysis and meta regression. *J Affect Disord* [Internet]. 2016 Jan 15;190:457–66.
  27. Schuch, F.B., Vancampfort, D., Firth., J., Rosenbaum., Ward, P.B., Silva, E., Hallgren, Dunn, AL., Deslandes, ., Fleck, MC., Carvalho, AF., & Stubbs B, Schuch FB, Vancampfort D, Firth J, Rosenbaum S, Ward PB, et al. Physical Activity and Incident Depression: A Meta-Analysis of Prospective Cohort Studies. *Am J Psychiatry* [Internet]. 2018 Jul 25;(in press)(7):631–48.
  28. Schuch FB, Stubbs B, Meyer J, Heissel A, Zech P, Vancampfort D, et al. Physical activity protects from incident anxiety: A meta-analysis of prospective cohort studies. *Depress Anxiety* [Internet]. 2019 Jun 17;
  29. Malik SH, Blake H, Suggs LS. A systematic review of workplace health promotion interventions for increasing physical activity [Internet]. Vol. 19, *British Journal of Health Psychology*. John Wiley & Sons, Ltd; 2014. p. 149–80.
  30. Kandola A, Lewis G, Osborn DPJ, Stubbs B, Hayes JF. Depressive symptoms and objectively measured physical activity and sedentary behaviour throughout adolescence: a prospective cohort study. *Lancet Psychiatry*. 2020;7:262–71.
  31. Helgadóttir B, Forsell Y, Hallgren M, Möller J, Ekblom Ö. Long-term effects of exercise at different intensity levels on depression: A randomized controlled trial. *Prev Med (Baltim)* [Internet]. 2017 Dec;105:37–46.
  32. Shrestha N, Kukkonen-Harjula KT, Verbeek JH, Ijaz S, Hermans V, Pedisic Z. Workplace interventions for reducing sitting at work. *Cochrane Database Syst Rev*. 2018;2018(6).
  33. Prince SA, Saunders TJ, Gresty K, Reid RD. A comparison of the effectiveness of physical activity and sedentary behaviour interventions in reducing sedentary time in adults: A systematic review and meta-analysis of controlled trials. *Obes Rev* [Internet]. 2014 Nov 1;15(11):905–19.
  34. Healy GN, Matthews CE, Dunstan DW, Winkler EAH, Owen N. Sedentary time and cardio-metabolic biomarkers in US adults: NHANES 200306. *Eur Heart J* [Internet]. 2011 Mar;32(5):590–7.
  35. Peachey MM, Richardson J, V Tang A, Dal-Bello Haas V, Gravesande J. Environmental, behavioural and multicomponent interventions to reduce adults' sitting time: A systematic review and meta-analysis. *Br*

- J Sports Med. 2020;54(6):315–25.
36. Kandola A, Lewis G, Osborn DPJ, Stubbs B, Hayes JF. Device-measured sedentary behaviour and anxiety symptoms during adolescence: A 6-year prospective cohort study. *Psychological Medicine*. 2020. In press.;
  37. Chau JY, Van Der Ploeg HP, van Uffelen JGZ, Wong J, Riphagen I, Healy GN, et al. Are workplace interventions to reduce sitting effective? A systematic review. *Prev Med (Baltim) [Internet]*. 2010;51(5):352–6.
  38. 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.
  39. Commissaris DACM, Huysmans MA, Mathiassen SE, Srinivasan D, Koppes LLJ, Hendriksen IJM. Interventions to reduce sedentary behavior and increase physical activity during productive work: A systematic review. *Scand J Work Environ Heal*. 2016;42(3):181–91.
  40. Cao C, Liu Y, Zhu W, Ma J. Effect of active workstation on energy expenditure and job performance: A systematic review and meta-analysis. *J Phys Act Heal*. 2016;13(5):562–71.
  41. Dupont F, Léger PM, Begon M, Lecot F, Sénécal S, Labonté-Lemoyne E, et al. Health and productivity at work: Which active workstation for which benefits: A systematic review. *Occup Environ Med*. 2019;76(5):281–94.
  42. Hutcheson AK, Piazza AJ, Knowlden AP. Work Site–Based Environmental Interventions to Reduce Sedentary Behavior: A Systematic Review. *Am J Heal Promot*. 2018;32(1):32–47.
  43. Josaphat KJ, Kugathasan TA, E.R. Reid R, Begon M, Léger PM, Labonté-Lemoyne E, et al. Use of Active Workstations in Individuals with Overweight or Obesity: A Systematic Review. *Obesity*. 2019;27(3):362–79.
  44. Torbeyns T, Bailey S, Bos I, Meeusen R. Active workstations to fight sedentary behaviour. *Sports Med*. 2014;44(9):1261–73.
  45. MacEwen BT, MacDonald DJ, Burr JF. A systematic review of standing and treadmill desks in the workplace. *Prev Med (Baltim) [Internet]*. 2015;70:50–8.
  46. Podrekar N, Kozinc Ž, Šarabon N. The effects of cycle and treadmill desks on work performance and cognitive function in sedentary workers: A review and meta-analysis. *Work*. 2020;65(3):537–45.
  47. Oakman J, Neupane S, Proper KI, Kinsman N, Nygård CH. Workplace interventions to improve work ability: A systematic review and meta-analysis of their effectiveness. *Scand J Work Environ Heal*. 2018;44(2):134–46.

48. Sui W, Smith ST, Fagan MJ, Rollo S, Prapavessis H. The effects of sedentary behaviour interventions on work-related productivity and performance outcomes in real and simulated office work: A systematic review. *Appl Ergon*. 2019;75(September 2018):27–73.
49. Ojo SO, Bailey DP, Chater AM, Hewson DJ. The impact of active workstations on workplace productivity and performance: A systematic review. *Int J Environ Res Public Health*. 2018;15(3).
50. Chu AHY, Ng SHX, Tan CS, Win AM, Koh D, Müller-Riemenschneider F. A systematic review and meta-analysis of workplace intervention strategies to reduce sedentary time in white-collar workers. *Obes Rev*. 2016;17(5):467–81.
51. Tew GA, Posso MC, Arundel CE, McDaid CM. Systematic review: Height-adjustable workstations to reduce sedentary behaviour in office-based workers. *Occup Med (Chic Ill)*. 2015;65(5):357–66.
52. Wang Y, Wu L, Lange JP, Fadhil A, Reiterer H. Persuasive technology in reducing prolonged sedentary behavior at work: A systematic review. *Smart Heal [Internet]*. 2018;7–8(May):19–30.
53. Healy GN, Eakin EG, Owen N, Lamontagne AD, Moodie M, Winkler EAH, et al. A Cluster Randomized Controlled Trial to Reduce Office Workers' Sitting Time. *Med Sci Sport Exerc [Internet]*. 2016 Sep 1;48(9):1787–97.
54. Edwardson CL, Yates T, Biddle SJH, Davies MJ, Dunstan DW, Esliger DW, et al. Effectiveness of the stand more at (SMARt) work intervention: Cluster randomised controlled trial. *BMJ [Internet]*. 2018 Oct 10;363:3870.
55. Gao L, Flego A, Dunstan DW, Winkler EA, Healy GN, Eakin EG, et al. Economic evaluation of a randomized controlled trial of an intervention to reduce office workers' sitting time: the "Stand Up Victoria" trial. *Scand J Work Environ Health [Internet]*. 2018 Sep 1;44(5):503–11.
56. Munir F, Miller P, Biddle SJH, Davies MJ, Dunstan DW, Esliger DW, et al. A Cost and Cost-Benefit Analysis of the Stand More AT Work (SMARt Work) Intervention. *Int J Environ Res Public Health [Internet]*. 2020 Feb 13;17(4):1214.
57. Healy GN, Eakin EG, Winkler EA, Hadgraft N, Dunstan DW, Gilson ND, et al. Assessing the Feasibility and Pre-Post Impact Evaluation of the Beta (Test) Version of the BeUpstanding Champion Toolkit in Reducing Workplace Sitting: Pilot Study. *JMIR Form Res [Internet]*. 2018 Aug 28;2(2):e17.
58. LaCroix AZ, Bellettiere J, Rillamas-Sun E, Di C, Evenson KR, Lewis CE, et al. Association of Light Physical Activity Measured by Accelerometry and Incidence of Coronary Heart Disease and Cardiovascular Disease in Older Women. *JAMA Netw open [Internet]*. 2019 Mar 1;2(3):e190419.
59. Nooijen CFJ, Blom V, Ekblom Ö, Heiland EG, Larisch L-M, Bojsen-Møller E, et al. The effectiveness of multi-component interventions targeting physical activity or sedentary behaviour amongst office workers: a three-arm cluster randomised controlled trial. *BMC Public Health [Internet]*. 2020 Dec

- 1;20(1):1329.
60. Lutz N, Clarys P, Koenig I, Deliens T, Taeymans J, Verhaeghe N. Health economic evaluations of interventions to increase physical activity and decrease sedentary behavior at the workplace: A systematic review. *Scand J Work Environ Heal*. 2020;46(2):127–42.
  61. Edwardson CL, Biddle SJH, Clarke-Cornwell A, Clemes S, Davies MJ, Dunstan DW, et al. 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 11 Medical and Health Sciences 1117 Public Health and Health Services. *BMC Public Health* [Internet]. 2018 Sep 14;18(1):1–13.
  62. Rovniak LS, Adams MA, Sciamanna CN, Kong L, Sullivan N, Costalas S, et al. Effects of Bluetooth-Enabled Desk Ellipticals on Office Work Performance: Rationale, Design, and Protocol for a Randomized Trial With Overweight and Obese Adults. *JMIR Res Protoc* [Internet]. 2020 Jan 14;9(1):e16275.
  63. Schoeppe S, Alley S, Van Lippevelde W, Bray NA, Williams SL, Duncan MJ, et al. Efficacy of interventions that use apps to improve diet, physical activity and sedentary behaviour: A systematic review. *Int J Behav Nutr Phys Act* [Internet]. 2016;13(1).
  64. Stephenson A, McDonough SM, Murphy MH, Nugent CD, Mair JL. Using computer, mobile and wearable technology enhanced interventions to reduce sedentary behaviour: a systematic review and meta-analysis. *Int J Behav Nutr Phys Act*. 2017;14(1):105.
  65. Compernelle S, Desmet A, Poppe L, Crombez G, De Bourdeaudhuij I, Cardon G, et al. Effectiveness of interventions using self-monitoring to reduce sedentary behavior in adults: A systematic review and meta-analysis. *Int J Behav Nutr Phys Act*. 2019;16(1).
  66. Direito A, Carraça E, Rawstorn J, Whittaker R, Maddison R. mHealth Technologies to Influence Physical Activity and Sedentary Behaviors: Behavior Change Techniques, Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Ann Behav Med*. 2017;51(2):226–39.
  67. Huang Y, Benford S, Blake H. Digital interventions to reduce sedentary behaviors of office workers: Scoping review [Internet]. Vol. 21, *Journal of Medical Internet Research*. Journal of Medical Internet Research; 2019. p. e11079.
  68. Firth J, Torous J, Nicholas J, Carney R, Prata A, Rosenbaum S, et al. The efficacy of smartphone-based mental health interventions for depressive symptoms: a meta-analysis of randomized controlled trials. *World Psychiatry* [Internet]. 2017 Oct;16(3):287–98.
  69. Buckingham SA, Williams AJ, Morrissey K, Price L, Harrison J. Mobile health interventions to promote physical activity and reduce sedentary behaviour in the workplace: A systematic review [Internet]. Vol. 5, *Digital Health*. SAGE Publications Inc.; 2019.

70. Howarth A, Quesada J, Silva J, Judycki S, Mills PR. The impact of digital health interventions on health-related outcomes in the workplace: A systematic review. *Digit Heal* [Internet]. 2018 Jan;4:205520761877086.
71. Haile C, Kirk A, Cogan N, Janssen X, Gibson AM, Macdonald B. Pilot testing of a nudge-based digital intervention (Welbot) to improve sedentary behaviour and wellbeing in the workplace. *Int J Environ Res Public Health* [Internet]. 2020 Aug 2;17(16):1–13.
72. Healy GN, Goode AD, Abbott A, Burzic J, Clark BK, Dunstan DW, et al. Supporting workers to sit less and move more through the web-based beupstanding program: Protocol for a single-arm, repeated measures implementation study. *J Med Internet Res* [Internet]. 2020 May 1;22(5).
73. 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 11 *Medical and Health Sciences 1117 Public Health and Health Services* [Internet]. Vol. 15, *International Journal of Behavioral Nutrition and Physical Activity*. BioMed Central Ltd.; 2018. p. 1–18.
74. Mackenzie K, Such E, Norman P, Goyder E. Sitting less at work: A qualitative study of barriers and enablers in organisations of different size and sector. *BMC Public Health* [Internet]. 2019 Jul 4;19(1):1–13.
75. Renaud LR, Speklé EM, van der Beek AJ, van der Ploeg HP, Pasma HR, Huysmans MA. The user and non-user perspective: Experiences of office workers with long-term access to sit-stand workstations. Weston KL, editor. *PLoS One* [Internet]. 2020 Jul 28;15(7):e0236582.
76. Mansfield L, Hall J, Smith L, Rasch M, Reeves E, Dewitt S, et al. “Could you sit down please?” A qualitative analysis of employees’ experiences of standing in normally-seated workplace meetings. Hadgraft N, editor. *PLoS One* [Internet]. 2018 Jun 26;13(6):e0198483.
77. Hall G, Laddu DR, Phillips SA, Lavie CJ, Arena R. A tale of two pandemics: How will COVID-19 and global trends in physical inactivity and sedentary behavior affect one another? [Internet]. *Progress in Cardiovascular Diseases*. W.B. Saunders; 2020.

## Appendices

**Table 1. Systematic reviews of studies investigating the relationship between sedentary behaviour and mental health or cognitive performance in working-age adults**

Study	Study number and setting	Definition of sedentary behaviour	Findings
<b>Depression</b>			<b>High sedentary behaviour is consistently associated with a higher chance of developing depression.</b>
Huang et al. (2020)	12 prospective studies.	Sedentary behaviour included watching TV (n=6), using computer (n=5), screen time (n=4), driving (n=1).	High sedentary behaviour was associated with an 10% higher risk of depression (RR=1.10, 95%CI 1.03 to 1.19), with mentally-passive sedentary behaviours (e.g., watching television) being associated with the greatest degree of risk (RR=1.18, 95%CI 1.07 to 1.30).
Wang et al. (2019)	19 studies, 12 cross-sectional and 7 longitudinal.	Sedentary behaviour as continuous (n=3) or cumulative for 4 hours a day (n=9), 2 hours a day (n=5), or 1 hour a day (n=2).	High screen-time was associated with 1.28 times greater odds of depression (OR=1.28, 95%CI, 1.17 to 1.39).
Zhai et al. (2015)	24 studies, 13 cross-sectional and 11 longitudinal.	Sedentary behaviour included inactivity, computer use, sitting time, TV viewing, screen time, media use and driving.	High sedentary behaviour was associated with a 25% increased risk of depression (RR=1.25, 95%CI 1.16 to 1.35). The risk was higher for prolonged computer or internet use (RR=1.22 95%CI 1.10 to 1.34) than television watching (RR=1.13 95%CI 1.06 to 1.21).
<b>Anxiety</b>			<b>High sedentary behaviour is consistently associated with a higher chance of developing an anxiety disorder.</b>
Allen et al. (2019)	13 observational studies, with 8 including participants over 18 years.	Sedentary behaviour included sitting time, TV time, computer time, screen time.	High sedentary behaviour was associated with 1.48 times higher odds of an anxiety disorder (OR=1.48, 95%CI, 1.25 to 1.75).

Teychenne et al. (2015)	9 studies, with 7 cross-sectional and 11 longitudinal.	Sedentary behaviour measured with self-reported physical activity questionnaires (n=7).	There was moderate evidence that high total sedentary behaviour and sitting time were associated with an increased risk of anxiety. There were no consistent differences between sedentary behaviour types and anxiety, such as watching television compared with using a computer.
<b>Quality of life</b>		<b>High sedentary behaviour is associated with reduced quality of life.</b>	
Boberska et al. (2018)	23 cross-sectional, 1 experimental and 3 longitudinal studies, with 18 included in meta-analysis.	Sedentary behaviour measured using self-report measures (n=23), with 4 studies using accelerometers.	Lower sedentary behaviour levels were associated with higher physical health-related quality of life (estimated average effect $r = -.140$ , 95%CI, $-.191$ to $-.088$ ).
<b>Cognition</b>		<b>High sedentary behaviour is associated with reduced cognitive performance, but findings are less consistent.</b>	
Loprinzi (2019)	25 studies, 2 experimental, 5 prospective and 10 cross-sectional.	Sedentary behaviour included TV viewing, computer use, reading, driving measured via self-report (n=15), with 7 using accelerometer.	The relationship between sedentary behaviour and memory was inconsistent and more research is necessary.
Falck et al. (2017)	8 studies, with 3 cross-sectional, 2 case control and 3 cohort.	Sedentary behaviour included self-reported TV viewing (n=2), or physical activity questionnaire (n=6).	6 of 8 studies found that high sedentary behaviour was associated with lower cognitive performance, including memory, executive functioning, processing speed, organisation and planning, and global cognitive function. However, study quality was generally low.

RR = risk ratio, OR = odds ratio

**Table 2. Systematic reviews of interventions to reduce excessive occupational sitting in the workplace**

Study	Type of review	Population	Interventions	Control groups	Change in sitting or activity	Other findings	Conclusions
<b>Environmental interventions</b>							
Cao et al. 2016	Systematic, with 16 studies of mixed designs including in a meta-analysis.	398 participants between the ages of 22 and 64 (M=36.6, SD=6.3), with studies including office workers and transcriptionists. Studies were mostly from the United States (US) (n=14) and the rest from Australia.	Environmental interventions used dynamic workstations e.g., treadmills for walking and working. One study used stationary bikes for cycling and working. Intervention time ranged from 5 minutes to 8 hours long (n=8), 2-16 days (n=2), and 9-12 months (n=2).	Seated working.	In 7 studies, dynamic workstations led to increased daily energy expenditure (mean effect size = 1.47, 95%CI, 1.22, 1.72).  Dynamic workstations led to increased calorie expenditure from 72-88 kcal per hour to 191-376 kcal per hour; increased steps by 2728 to 6111 per day, and increased walking time (58 to 177 min/day) compared to sitting.	In 9 studies, dynamic workstations led to a decrease in typing speed and mouse-clicking.  Cycling interventions led to a decrease of 3% to 5% in mouse-clicking, while walking interventions reduced 8% to 15%.  Dynamic workstations did not affect selective attention, processing speed, speech quality, reading comprehension, or transcription.	Dynamic workstations increased daily activity and reduced workplace sedentariness. Dynamic workstations reduced some aspects of job performance requiring movement but no impact on cognitive performance. Cycling interventions had less of an effect on typing and mouse clicking than walking interventions.
Dupont et al. 2019	Systematic, with 12 studies	414 participants with mean age 30.1. Most studies	Environmental interventions used dynamic workstations, including sit-stand and	Comparison group.	Compared to sit-stand desks, treadmill desks increased energy	Treadmill desks and under-desk pedalling reduced	Under-desk pedalling and treadmill desks increased energy

	of mixed designs.	included healthy office-workers.	treadmill desks, and under-desk pedalling.  Intervention time ranged from 35 minutes to 1 working day.		expenditure by 1 to 1.2 metabolic equivalents. Under-desk pedalling increased energy expenditure by 2.9 to 6.9 kcal/min.	typing speed compared with sit-stand desks.  There was no difference between sit-stand and treadmill desks, and under-desk pedalling on divided attention and short-term auditory-verbal memory. Treadmill desks and under-desk pedalling reduced boredom compared to sit-stand. Treadmill desks also reduced stress.	and calorie expenditure compared to sit-stand.  Typing speed decreased with a treadmill desk compared to sit-stand. Treadmill desks reduced job performance for computer-related work but also decreased stress and boredom.
Josaphat et al. 2019	Systematic with 19 studies, including 7 RCTs and 12 studies of mixed design.	741 overweight or obese mostly office workers with a mean age of 37.4 (SD=9.1). Two studies included school children.	Environmental interventions used dynamic workstations, including sit-stand desks (n=12), treadmill desks (n=9), under-desk pedalling (n=3), and stepping desks (n=1).  Intervention time ranged from 1 hour to 1 year.	Standard desk/ No intervention.	Stand-sit desks led to a decrease in workplace sitting time. Treadmill desks were more effective than sit-stand desks at increasing energy expenditure. Under-desk pedalling produced larger increases in energy expenditure for overweight or obese participants.	Participants reported a 46% increase in concentration with stand-sit desks and reported better work performance with treadmill desks than baseline.	All types of dynamic workstations increased activity and reduced sedentariness.  In overweight or obese individuals, treadmill desks offer a promising intervention to

					<p>There were no clear differences in sedentary time between sit-stand, and treadmill desks, and under-desk pedalling.</p> <p>Longer interventions were associated with increased walking time during work hours using a treadmill desk.</p>		reduce sedentariness.
Neuhaus et al. 2014	Systematic, with 8 RCTs and 30 studies of mixed design included in the meta-analysis.	984 participants, between the ages of 18 and 64 (M=35.5, SD=6.4). Studies were conducted in US, Europe, Asia, and Australia, with most studies including office workers (n = 23).	<p>Environmental interventions used dynamic workstations, including height adjustable desk (n=17), sit-stand desks (n=10), treadmill desk (n=12), under-desk pedalling or cycle ergometer (n=4), and stepping desks (n=1).</p> <p>The interventions lasted &lt;1 day in experimental studies, and on average 15 weeks in field studies.</p>	Mixed.	Most studies reported a reduction in occupational sedentary time, with a pooled effect size of -77 minutes per 8-hour workday (95%CI, -120, -35 mins/day). At 1 week, reduction in occupational sedentary time was 143min per workday (95%CI, -184, -102 min/day) and 137 min per workday at 3 months (95%CI, -179, -95 min/day).	Dynamic workstations did not affect 84/112 work-related outcomes reported in 23 studies. 21 studies reported short-term reductions in work performance, mostly from treadmill desks.	Dynamic workstations effectively reduced occupational sedentary behaviour, are unlikely to cause long-term reductions in work performance, and may improve wellbeing.
Torbeyns et al. 2014	Systematic with 27 studies	674 participants with a mean age of	Environmental interventions used dynamic workstations,	Mixed.	Most interventions in adults led to reduced	Sit-stand desks increased energy, focus, and	Dynamic workstations

	conducted with adults, including 15 RCTs.	32.1 (SD=7.1). Adults were mostly office-workers or hospital and university staff.	including sit-stand (n=11), treadmill desk (n=12), under-desk pedalling (n=1), walking and pedalling (n=1), walking, and elliptical (n=1), walking and stepping device (n=1).  Intervention time ranged from 1 week to 1 year.		sitting. Sit-stand desks reduced sitting by -66 to -143 minutes per day. Treadmill desks reduced sedentary time with an increase of 2000 steps per day. Under-desk pedalling led to a decrease in time spent being sedentary.	productivity in one study and no changes in another. Treadmill desks decreased computer task performance for mouse-clicking and typing but did not affect cognitive tasks.	decreased sitting at work without affecting work performance.
<b>Behavioural interventions</b>							
Chau et al. 2010	Systematic, 5 RCTs, and 1 pre-post design included.	3,347 participants between the ages of 39 and 45. Studies were conducted in Canada, Australia, and Western or Northern Europe. Workplaces included universities and middle-to-large sized companies.	Behavioural interventions used individually tailored advice or counselling (n=3), physical activity counselling plus fitness test (n=1), weekly healthy eating or active living email (n=1), and walking prompts with a pedometer (n = 1). Follow up time ranged between 78% and 98% in 4 studies.	No intervention/ waitlist (n=3).	Behavioural interventions led to no significant differences in sitting between intervention and control or comparison groups.  All studies used subjective (self-report) measures of sitting.	Not reported.	Behavioural interventions alone were insufficient to increase workplace activity or reduce sedentariness. However, there were studies with sitting as a primary outcome.
<b>Environmental and behavioural interventions</b>							
Commissaris et al. 2016	Systematic with 40 studies of 41	11,685 participants with a mean age of 42.8 (SD=9.42).	Environmental interventions used dynamic workstations, including sit-stand desks	Regular workstations/no interventions.	There was strong evidence that treadmill desks reduced sedentary	There was conflicting or insufficient evidence for	Dynamic workstations effectively reduced

	interventions, including 8 RCTs and 32 studies of mixed design.	Most studies included office-based workers in addition to hospital and university staff.	(n=10), treadmill desks (n=8), and under-desk pedalling (n=2).  Behavioural interventions used personalised goal setting and feedback via prompts or messages (n = 10) and the promotion of stair use (n=11).  Intervention time ranged from 1 day to 1 year, and follow-up time ranged from 1 week to 4 months.		behaviour and moderate evidence for sit-stand desks reducing sedentary behaviour at work.  Promoting stair use interventions showed insufficient evidence for reducing sedentary behaviour at work.  Personalised behaviour interventions with self-monitoring showed to be ineffective in reducing sedentary behaviour at work.	any interventions affecting workplace performance.	total daily sitting, but it remains unclear if this applied to the workplace specifically.
<b>Environmental, behavioural, and multicomponent interventions</b>							
Chu et al. 2016	Systematic with 15 RCTs, and 11 studies of mixed designs included in the meta-analysis.	4,568 white-collar workers between the ages of 33.5 and 50.4. Studies were conducted in the US, Australia, and Western or Northern Europe.	Environmental interventions used sit-stand desks, under-desk pedalling, and treadmill desks.  Behavioural interventions used motivational interviewing, goal setting, action planning, prompt	No intervention (n=21).	12 studies reported a reduction in occupational sitting of -39.6 minutes per 8-hour workday (95%CI, -51.7, -27.5 min/day).  Multicomponent interventions led to a reduction of -88.8 minutes	Not reported.	Behavioural, environmental, and multicomponent interventions effectively reduced occupational sitting. Multicomponent approaches were most effective.

			<p>self-monitoring of behaviour.</p> <p>Multicomponent interventions used sit-stand desks in combination with behavioural interventions for example, goal-setting, self-monitoring, prompts, or problem-solving.</p> <p>Intervention time ranged from 5 days to 14 months and follow up ranged from 7 weeks to 12 months.</p>		<p>per workday sitting (95%CI, -132.7, -44.9 min/day);</p> <p>Environmental interventions led to a decrease of -72.8 minutes per workday (95%CI, -104.9, -40.6 min/day).</p> <p>Behavioural interventions led to a reduction of -15.5 minutes per workday (95%CI, -22.9, -8.2 min/day).</p>		
Hutcheson et al. 2019	Systematic, with 15, mostly RCT, studies included.	524 participants aged between 33 and 49 years. Studies were conducted in the US, UK, Australia, and Canada; and included office workers from university, health and government workplaces.	<p>Environmental interventions used dynamic workstations, including sit-stand desks (n=10), treadmill desks (n=3), or under-desk pedalling (n=2).</p> <p>Behavioural interventions used prompting technology (n=1).</p>	Waitlist/ Usual care/Alternative intervention.	<p>14 studies reported a reduction in sedentary behaviour ranging from 18 minutes to 233 minutes.</p> <p>Sit-stand desk led to a reduction in sitting from 19.7 to 125 minutes a day.</p> <p>Treadmill desks led to a reduction in sitting of 233 minutes at 3 months, and 87 minutes at 9 months.</p>	One study found no changes in work performance from dynamic workstations.	Environmental workplace interventions were effective in reducing sedentary behaviour.

			<p>Multicomponent interventions used dynamic workstations in addition to emails, training sessions, coaching, self-monitoring, or motivational interviewing.</p> <p>Interventions time ranged from 5 days to 9 months, with two studies including a follow up at 3 months.</p>		<p>Prompting technology led to reduction sitting of 18 minutes a day.</p> <p>Multicomponent interventions led to a reduction in sitting of 89 minutes a day.</p>		
Lutz et al. 2020	Systematic, with 18 economic evaluations, including 11 RCTs, 7 cohort studies, and 1 model-based study.	60 to 1260 participants in the RCTs and 25 to 63,646 participants in the other studies. Studies were conducted in the US, Australia, and Western Europe, with working-age adults.	<p>Environmental interventions included table tennis, exercise balls, relaxing zones, and yoga sessions.</p> <p>Behavioural interventions included prompts, counselling, pedometers, financial incentives, motivational interviews, and promotion of stair use.</p> <p>Multicomponent interventions included</p>	No intervention/Waitlist or alternative intervention.	<p>Interventions reduced sedentary behaviour in some studies, but only one intervention produced changes that were significantly different from zero.</p> <p>Interventions increased physical activity in 6 of 20 effect sizes.</p>	Insufficient data to assess the cost-effectiveness of interventions.	<p>Most studies found that interventions reduced sedentary behaviour and increased physical activity were effective, but the evidence was inconsistent, and effect sizes varied.</p> <p>Only one study had sedentary behaviour as a primary outcome, which</p>

			<p>counselling techniques and sit-stand desks.</p> <p>Intervention time ranged from 6 months to 5 years.</p>				<p>produced the largest effect. Interventions were highly varied, and it is unclear whether one type of intervention is superior to another.</p>
<p>Peachey et al. 2020</p>	<p>Systematic with meta-analysis of 35 studies of RCT design.</p>	<p>5983 participants aged between 18 and 70 years. 18 studies focused on the workplace alone. Studies were conducted in the US, Europe, Australia, and Canada, with mostly overweight, obese, or physically inactive adults.</p>	<p>Environmental interventions used sit-stand desks, under-desk pedalling or treadmill desks.</p> <p>Behavioural interventions used prompts which were screen-based, computer-based or wrist-worn.</p> <p>Multicomponent interventions (n=9) used a combination of behavioural, environmental, and educational techniques, such as counselling, activity tracker, web-based programme with tailored feedback, educational booklets, websites, emails.</p>	<p>Waitlist/Other intervention/No intervention.</p>	<p>29 studies reported a significant reduction in daily sitting time, including behavioural (n=12), environmental (n=8), and multicomponent (n=8) interventions.</p> <p>Significant reduction in daily sitting time of -30.37 minutes per day (95%CI, -40.86 to -19.89 min/day) favouring the intervention group. Reductions in sitting time were similar between workplace (-29.96 min/day, 95%CI, -44.05 to -15.87 min/day) and other settings (-30.47 min/day, 95%CI, -44.68 to -16.26 min/day).</p>	<p>Not reported.</p>	<p>There was consistent evidence of reductions in sedentary behaviour across intervention type and setting.</p>

			<p>Intervention length ranged from 1 day to 1 year.</p> <p>Follow-up time ranged from 2 weeks to 2 years.</p>		<p>Workplace only interventions (n=18) led to a reduction of -29.96 in sedentary behaviour (95%CI, -44.05, -15.87 min/day).</p>		
Shrestha et al. 2018	<p>Systematic, with 24 RCTs, 2 cross-over, and 8 pre-post designs included in the meta-analysis.</p>	<p>3,397 participants from academic institutes (n=9), healthcare (n=2), or companies (n=23). All studies were conducted in high-income countries.</p>	<p>Environmental interventions used dynamic workstations such as sit-stand desks (n=16)</p> <p>Cultural interventions used walking strategies, sitting diaries, and planned breaks (n=4)</p> <p>Educational interventions used feedback, counselling, prompts, and leaflets (n=11)</p> <p>Multicomponent interventions used dynamic workstations and motivational interviewing (n=4).</p>	<p>No intervention (n = 23) or other.</p>	<p>Sit-stand desks alone or with information and counselling reduced sitting by around 100 minutes per 8-hour workday (95%CI, -116, -84 min/day) in short-term studies. Reductions were smaller in longer studies, with -57 minutes per day (95%CI, -99 to -15 min/day) at medium-term follow-up.</p> <p>Walking strategies did not reduce occupational sitting time. Periodic mini-breaks reduced occupational sitting time by 40 minutes per day (95%CI, -66, -15 min/day).</p>	<p>Not reported.</p>	<p>Sit-stand workstations alone or as multicomponent interventions reduced sitting, but the quality of evidence was low. The large variety between interventions, lack of long-term follow-ups (most &lt;1 year), and small sample sizes make comparisons and firm conclusions difficult.</p>

			Follow up of interventions were either short-term lasting less than 3 months (n=25) or medium term lasting between 3 and 12 months (n=9).		Information, feedback, counselling reduced sitting by 28 minutes at medium-term follow-up (95%CI -51, -5 min/day). Prompts reduced sitting by 55 minutes a day at medium-term follow ups (95%CI, -96, -14 min/day).  Multicomponent interventions reduced sitting time by 101 minutes per 8-hour workday (95%CI, -117.27, -84 min/day) and prolonged bouts of sitting in the short-term.		
<b>Environmental or behavioural and multicomponent interventions</b>							
Tew et al. 2015	Systematic, with 5 studies of non-randomised trials (n=4) and	172 participants between the aged of 35 and 43. Studies were conducted in the US and Australia, with	Environmental interventions used sit-stand desks (n=5).  Multicomponent interventions used dynamic workstations with health	No intervention.	All studies found that interventions reduced occupational sitting, with reductions ranging from 14% (95%CI, 11, 17%) to 21% (95%CI, 18, 25%).	As a result of adjusting to new workstations, some studies reported an increase in fatigue at the start of interventions.	Sit-stand desks reduced occupational sitting in office workers with additional benefits when

	cross-over (n=1) designs.	mostly office workers from health and safety-based fields.	coaching, emails, educational booklet, or prompts.  Intervention time ranged from 4 weeks to 3 months.		Multicomponent intervention led to reductions in sedentary behaviour of 56 minutes (95%CI, -107, -4 min/day) compared to the control groups.		delivered as a multicomponent intervention.
Wang et al. 2018	Systematic with 8 studies, including 6 RCTs.	Studies were conducted in Australia and Western Europe, with 702 participants of mostly office workers.	Behavioural interventions used step monitoring, PC-based prompts, and web-based tailored interventions.  Multicomponent interventions used environment and behavioural components (n=2). For example, sit-stand desks and screen prompts, or workshop and prompts from a chair sensor.  Intervention time ranged from 5 days to 12 months.	Mixed.	3 interventions reported a reduction in prolonged sitting compared to controls.  One intervention with organisational support and activity tracker components produced reductions in total occupational sitting by -35.5 minutes per 10-hour workday (95%CI, -60.9, -10.2 min/day) and prolonged sitting by -45.7 minutes per workday (95%CI, -84, -7.4 min/day).	Not reported.	Interventions using digital prompts reduced sitting during work, but evidence focusing on these interventions is lacking.

Abbreviations: M = mean; SD = standard deviation; CI = confidence interval; RCT = randomised controlled trial; g = Hedge's g; IQR = interquartile range; SE= standard error

Table 3: Systematic reviews of digital interventions for reducing excessive sitting

Study	Type of review	Population	Interventions	Control groups	Change in sitting/activity	Conclusions
Compernelle et al. 2019	Systematic with 19 studies of mixed designs, 16 included in a meta-analysis.	2800 adults with mean ages ranging from 18 and 60. Studies were conducted in the US, UK, Belgium, Australia, Canada, Japan, and Taiwan, with half conducted in healthy populations, and half in people with chronic illnesses, or who were overweight or obese.	Self-monitoring interventions used sensors such as pedometers (n=6), or accelerometers (n=9). Self-report interventions used electronic logbooks or questionnaires (n=4).  Intervention time ranged from 1 week to 1 year.	No intervention or intervention without self-monitoring.	Self-monitoring interventions reduced total ( $g = 0.32$ ; 95%CI, 0.14, 0.50) and occupational sedentary behaviour ( $g = 0.49$ , 95%CI, 0.07, 0.90).  Interventions led to a reduction of - 34.37 minutes per day (95%CI, 14.48, 54.25 min/day) in total sedentary behaviour compared to controls. There was no effect on increasing the frequency of breaks.  Only interventions that included sensors led to a reduction in sedentary behaviour ( $g = 0.40$ , 95%CI, 0.19, 0.02). Interventions targeting both sedentary behaviour	Self-monitoring interventions with feedback led to small reductions in total and occupational sedentary behaviour  Interventions were most effective when only focusing on sedentary behaviour.  More work is necessary to clarify how much of these effects are due to self-monitoring, as all studies were a part of multicomponent interventions.

					and physical activity had less influence on behaviour.	
Direito et al. 2017	Systematic with 21 RCTs included in the meta-analysis.	1701 participants with a median age of 40.1 (range, 8.4-71.7). Studies were conducted in the US, Canada, Australia, and Europe.	All but one study included multicomponent interventions using personal digital assistants, mobile phone, SMS or email messages (e.g., tailored, plan or goal reminders), sensors (e.g., pedometers or SenseWear Armbands), printed material, consultations or counselling, smartphone applications (e.g., social influencing or counselling applications), tablet computers, and websites (e.g., Twitter).  The median follow-up time was 9 and ranged from 1 to 52 weeks.	Usual care/non-technology comparison intervention.	5 interventions led to a reduction in sedentary behaviour (SMD = -0.26, 95%CI -0.53, -0.00) compared to controls. TV viewing duration significantly reduced when using smartphone apps. There was no difference between studies using devices (SMD = -0.24, 95%CI, -1.00, 0.52) or self-report measures of sedentary behaviour (SMD = -0.27, 95%CI, -0.55, 0.01).	Interventions using smartphone-based technologies produced small decreases in daily sedentary behaviour and increases in walking.
Schoeppe et al. 2016	Systematic review, with 27 studies, 19 of which were RCTs.	2189 participants with a mean age of 41.5 (ranging from 18 to 71 years). Studies were mostly conducted in the	Newly designed smartphone applications (n=15) used self-monitoring, educational information, social networking, action planning, and motivational messaging. Commercially available smartphone applications (n=12)	Comparison group/Usual care/No intervention.	Two studies examined sedentary behaviour, and one found a reduction in total daily sitting time while watching television after 8 weeks of follow-up. The intervention involved three newly designed apps: 1) analytic, focusing	Smartphone applications reduced total sitting time, but the evidence is limited.

		US, Australia, New Zealand, Europe, and the Middle East.	<p>used step monitoring, feedback, goal setting, and immersive gaming.</p> <p>Multicomponent interventions used an app with education, counselling, printouts, emails, website, and pedometer (n=13).</p> <p>On average, interventions lasted 10 weeks, and had a follow-up at 12 weeks (n=9).</p>		<p>on goal setting and feedback, 2) social, focusing on competition and collaboration, 3) affective, focusing on positive reinforcement and modelling.</p>	
Stephens et al. 2017	Systematic, with 17 RCTs and 15 included in a meta-analysis.	1967 participants between the ages of 18 and 70, with most studies in the workplace.	<p>Workplace and community or home interventions (n=2) used environmental changes, e.g., under-desk pedalling, computer prompts, websites, pedometers, and motivational emails, calls or texts.</p> <p>Workplace interventions (n=10) used environmental changes, e.g., sit-stand or treadmill desks (n=3) within multicomponent interventions that included educational or motivational texts and emails, websites, feedback,</p>	Waitlist/No intervention/Other intervention	<p>Computer, mobile, and wearable device-based interventions led to -41.28 fewer minutes per day of sedentary behaviour (95%CI, -60.99, -21.58) compared to controls.</p> <p>Workplace interventions (n = 8) reduced sedentary behaviour by -39.88 minutes per workday (95%CI, -59.58, -20.18) compared to controls. The effect was larger in medium-term follow-ups (-69.34 minutes per workday, 95%CI, -140.58, 1.91, n = 3) than short-</p>	Computer, mobile, and wearable technology interventions reduced total and workplace sedentary behaviour. Workplace interventions were most effective in longer studies, whereas interventions targeting total daily sitting led to smaller reductions in the medium and long-term.

			<p>computer prompts, reminder emails, and mindfulness sessions.</p> <p>Intervention time ranged from 5 days to 24 months. Studies included short (&lt;3 months), medium (&gt;3-6 months), and long-term (&gt;6 months) follow-up ranging from 5 days and 12 months.</p>		<p>term follow-ups (-35.23 minutes per workday, 95%CI, -47.60, -22.86, n = 5).</p> <p>Interventions targeting total daily sitting (n = 7) led to a -45.11 minutes per day reduction (95%CI, -86.63, -3.60 min/day). There was a greater reduction with short-term follow ups (-67.72 min/day, 95%CI -132.82, -2.62 min/day, n = 5) than medium (-5.92 min/day, 95%CI -21.32, 9.48, n = 2 min/day), or long-term (-4.71 min/day, 95%CI -32.81, 23.40, n = 2).</p>	
Buckingham et al. 2019	Systematic review with 25 mixed design studies.	73,354 participants from workplace settings in the US, Australia, Canada, Europe and Singapore.	<p>Wearable activity monitors or trackers (n=11), smartphone apps (n=6), or a combination of the two (n=8). Additional technology components included motivational or persuasive text messages (n=3) or emails (n=1), computer software or websites (n=14) and social media (n=1).</p> <p>Multicomponent interventions (n=14) involved educational</p>	No intervention/Comparison group/Usual treatment	40% (4/10) of studies reported a significant reduction in sedentary time. Interventions reducing sedentary time included activity monitor with SMS, a smartphone app, or counselling, or a standalone app.	Digital interventions in the workplace effectively reduced sedentary behaviour. However, findings are mixed and require longer-term follow-ups.

			<p>material (n=10), managerial support (n=2), financial incentives or rewards (n=10), counselling (n=3) and feedback (n3).</p> <p>Interventions ranged from 1 to 12 months with follow up ranging from 6 weeks to 12 months.</p>			
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*Abbreviations: M = mean; SD = standard deviation; CI = confidence interval; RCT = randomised controlled trial; g = Hedge's g; SMD= standardised mean difference.*