SEDENTARY BEHAVIORS AT WORK

EDITED BY: Frederic Dutheil, Yolande Esquirol and Martine Duclos

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SEDENTARY BEHAVIORS AT WORK

Topic Editors:
Frederic Dutheil, Centre Hospitalier Universitaire de Clermont-Ferrand, France
Yolande Esquirol, INSERM U1027 Epidémiologie et analyses en santé publique: Risques, Maladies Chroniques et Handicap, France
Martine Duclos, Centre Hospitalier Universitaire de Clermont-Ferrand, France

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Editorial: Sedentary Behaviors at Work

Frederic Dutheil[1], *Martine Duclos*[2] *and Yolande Esquirol*[3]*

[1] Université Clermont Auvergne, CNRS, LaPSCo, Physiological and Psychosocial Stress, University Hospital of Clermont-Ferrand, CHU Clermont-Ferrand, Preventive and Occupational Medicine, WittyFit, Clermont-Ferrand, France, [2] Université Clermont Auvergne, CRNH, INRA UMR-1019, University Hospital of Clermont-Ferrand, CHU Clermont-Ferrand, Sport Medicine and Functional Explorations, Clermont-Ferrand, France, [3] Université Paul Sabatier Toulouse 3, INSERM UMR-1027, University Hospital of Toulouse, CHU Toulouse, Occupational and Preventive Medicine, Toulouse, France

Keywords: sdentary behaviors, sedentariness, sitting time, intervention, prevention, occupation, job

Editorial on the Research Topic

Sedentary Behaviors at Work

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Edited and reviewed by:
Paolo Vineis,
Imperial College London,
United Kingdom

***Correspondence:**
Yolande Esquirol
esquirol.y@chu-toulouse.fr

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The aim of this Research Topic on "Sedentary behaviors at work" was to provide a multidisciplinary focus on this area of research. We aimed to give the reader a global overview of sedentary behaviors at work through addressing various aspects. Sedentary behaviors are a leading cause of preventable mortality in developed countries. We mainly have sedentary behaviors at work. Therefore, sedentary behaviors must be considered as an occupational risk, and must be a major concern both for companies/managers and physicians/health researchers (1, 2). However, sedentary behaviors at work were only studied recently over the past decade and many aspects are still poorly studied. This compilation of several relevant original articles and reviews is the result of the contribution of multidisciplinary researchers from several institutes promoting health and prevention. We would like to thank the authors for sharing their exciting work, showing the wide growing interest on this Research Topic, with eminent specialists ranging from medicine and physiology, to psychology, economics, or engineering. Readers may find this editorial a helpful guide to provide an overview of our Research Topic on "Sedentary behaviors at work."

The health benefit effects of a regular leisure physical activity are well-demonstrated and well-known but the difficulties to meet recommendations defined by World Health Organization remain and thus, physical inactivity affects still a large population of healthy adults. Moreover, the changes, in human activity occurred in the last decades in response to globalization and technology challenges, have transformed occupational and leisure activities toward sedentariness periods at work (prolonged sitting time at office) and also in leisure time (watching TV, video games). Thus, sedentary behaviors become a major concern of modern society and their health detrimental consequences are well-established or strongly suspected on some chronic disease such as cardiovascular disease and cerebrovascular events (Hupin et al.).

SEDENTARINESS: A BEHAVIOR BETTER AND BETTER DEFINED

First, sedentariness needs a clear definition (Magnon, Dutheil et al.). Indeed, being physically active does not prevent from having a sedentary behavior. Given the complexity of implicated mechanisms, the distinction between physical inactivity and sedentary lifestyle is important to explain for well-assessing the consequences of sedentary behavior and its interactions with leisure physical activity on health, as debated in two mini-review (Panahi and Tremblay; Thivel et al.).

Given the large part of wake-up time spent at work, people are mainly concerned by sedentariness during their working period.

Therefore, the second question is focused on "how to measure the sedentary ay work?" A systematic review (Boudet et al.) reports several available methods as standardized questionnaires but also more objectively measurements based on visual observations, cardiorespiratory assessment and also more modern technics as global positioning system, smartwatches and smartphones or pressure sensors. Their use in workplace, their advantages and disadvantages have been discussed and interesting recapitulative schemes are provided to clarify the type of available tools.

INTERVENTIONAL PROGRAMS TO REDUCE SEDENTARINESS: WHAT WE DO KNOW?

The last years, preventive interventional programs to fight the sedentariness at work have been emerged in companies to increase the level of physical activity in workplace, in particular among inactive office workers. Several programs are presented and discussed in this topic.

The results obtained after 5- month workplace physical intervention have shown a significant improvement of some anthropometric and fitness measurements among sedentary workers who spent long time/day in front of their computers, findings depending on the level of leisure physical activity at baseline (Genin et al.).

A systematic review was performed to identify the potential effects on cognitive performance when interventions in work environment to reduce sedentariness are implemented. Even if the contrasted results do not allow to conclude firmly to an association between changes in cognitive functioning and the decrease of sedentariness at work, the authors propose several factors to be considered in future researches to improve the homogeneity and the comparison of studies (duration of interventions, daily physical activity, testing time, age, and tools used to measure the sedentariness) (Magnon, Vallet et al.).

To break-up sitting time among desk-based office workers, some new work-stations are proposed but probably insufficiently implemented in companies. These programs question about the facilitators or barriers to implement worksite physical activity and to have a true change in habits. The original qualitative study conducted in thirty employees identified three categories of barriers or facilitators, varying with the stage of change (Planchard et al.). Employees constitute the study- population most often investigated in research studies, however the points of view of employers who allow these potential changes in their companies are also important to consider. From a truck driving population, the perceived value of reducing behavior is explored by interviews. Although, sedentariness is not considered as a priority risk, the potential positive effects of reducing sedentariness programs are reported (Mullane et al.).

A systematic review wants to update our knowledge on a novel concept. Indeed, although it is rarely considered in studies, organizational culture and sedentary behaviors could play a critical role in the success of workplace interventions (Taylor et al.).

Mitigate sitting time by the alternating between stand and sit postures is the aim of most of interventional programs. The ideal solution is currently not found. A United States team explored the preliminary efficacy, preference, and acceptability of two workplace points-of-choice prompt interventions to modify the sedentary behavior among desk-based office workers: a easy and poor cost solution for interesting results! (Larouche et al.).

AND IF SEDENTARINESS WAS A PROBLEM NEEDING A CHANGE BEHAVIOR VERY EARLY IN OUR LIFE?

Indeed, habitual physical activity level of an adult is also partly determined by the level of physical activity in childhood; examine the possibility to complement the school physical program by promoting physical recreational activity during school recess and measure the effect at long-term (Baquet et al.).

The published articles on this topic help to determine the ways of future researches, notably by contributing to recognize sedentariness at work as an occupational risk and to implement preventive programs in companies. No doubt, that this topic will be developed in up-coming years!

AUTHOR CONTRIBUTIONS

FD, MD, and YE contributed to writing this Editorial of the Research Topic on Sedentary Behaviors at Work.

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SYSTEMATIC REVIEW
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Sedentary Behavior at Work and Cognitive Functioning: A Systematic Review

Valentin Magnon[1], *Guillaume T. Vallet*[2] *and Catherine Auxiette*[2]*

[1] *Université Clermont Auvergne, UFR de Psychologie, Sciences Sociales, Sciences de l'Éducation, Clermont-Ferrand, France,* [2] *Université Clermont Auvergne, CNRS, LaPSCo, Clermont-Ferrand, France*

Background: It is now well-established that sedentarity has a negative impact on the physiological functioning and health of humans, whereas very little is known about the psychological repercussions, especially in cognitive functioning. Yet, studying the cognitive effects of the sedentary lifestyle is particularly relevant in the short term for productivity and in the long term for cognitive health (accelerated aging). This systematic review therefore aims to make an inventory of the potential cognitive effects of sedentarity at the workplace.

Methods: Pubmed, PsycINFO, Cochrane, Web of Science, and Scopus were searched for English-language peer-reviewed articles published between January 1, 2000 and December 31, 2017 to identify studies including sedentary behavior and objective measures from cognitive domains (cognitive inhibition, cognitive flexibility, working memory, etc.). To carry out this systematic review, the 3 keywords "Sedentary" and "Cognition" and "Work" (and their derivatives) had to appear in the title or in the summary of the paper.

Results: Of the 13 papers that met the inclusion criteria, 9 were short-term interventions, 3 medium-term interventions, and 1 long-term intervention. Nine of them reported non-significant results. Two studies study reported deterioration in cognitive performance. Two reported an improvement in performance in cognitive tasks with one study with overweight adults and the only one study with a long-term intervention. However, these studies intend to reduce sedentary behavior, but do not allow answering the question of the potential cognitive effects of the sedentary lifestyle.

Conclusion: These data suggest that sedentary behavior is not associated with changes in cognitive performance in interventions that intend to reduce sedentary behavior. Then, and given the trend toward increased time in sedentary behavior, long-term prospective studies of high methodological quality are recommended to clarify the relationships between sedentary behavior and the cognitive functioning. Our systematic review identifies also the need for retrospective, longitudinal, or epidemiologic studies. It also recognizes the need to standardize methodology for collecting, defining, and reporting sedentary behavior and the need to standardize the cognitive tests used. The relationship between sedentary behavior and cognitive functioning remaining uncertain, further studies are warranted for which 8 recommendations are proposed.

Keywords: sedentariness, sedentary behavior, cognition, work, cognitive functioning

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Edited by:
Yolande Esquirol,
INSERM U1027 Epidémiologie et Analyses en Santé Publique: Risques, Maladies Chroniques et Handicap, France

Reviewed by:
Sok King Ong,
Universiti Brunei Darussalam, Brunei
Yuke Tien Fong,
Singapore General Hospital, Singapore

***Correspondence:**
Catherine Auxiette
catherine.auxiette@uca.fr

Specialty section:
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INTRODUCTION

Humans' way of life has changed dramatically over the millennia. Originally a nomadic species, then hunter-gatherers, most humans are now fixed in one place for life. This physical anchorage is also found in daily behavior. Humans have become sedentary. Among the distribution of activities in a typical day (excluding sleeping), the time spent at work is of the greatest significance. It is therefore particularly relevant to study the effects of sedentarity at work, especially for occupations that involve sitting at an office (1). Moreover, while the impact of sedentarity on health is well established (2, 3), its effects on the cognition remain poorly understood (4). The objective of this systematic review is thus to identify the effects of sedentarity at work on cognition.

A sedentary lifestyle has become the default modern lifestyle in most societies. Currently, a sedentary behavior is defined by "any waking behavior characterized by an energy expenditure ≤1.5 metabolic equivalent of task (METs), while in a sitting, reclining or lying posture" (5). Nonetheless, stationary standing, which is often associated with an energy expenditure <1.5 METs, does not produce the same effects as prolonged sitting on human physiology (Magnon et al., in revision). Indeed, sitting has negative effects on postprandial glycemic metabolism (6) resulting in a decrease in lipoprotein lipase enzyme activity (7), which causes a reduction in triglyceride hydrolysis and a decreased glucose evacuation. On the other hand, standing allows a reduction of postprandial glucose and insulin; it is therefore sufficient to get up regularly (e.g., every 20 min) or to work standing (8–11) to avoid these effects. Consequently, standing cannot be considered as a sedentary behavior even if in the past it has been categorized as such (12).

Strictly sedentary behaviors, including sitting, are recognized for their negative effects on health in the medium and long term. They increase the probability of developing type II diabetes (13), cardiovascular diseases (14), musculoskeletal disorders (MSD) (15), and even some cancers (breast, colon, colorectal, endometrial, epithelial ovarian) (2). Although some of the deleterious effects of sedentary behaviors on physical health are becoming better understood, their psychological consequences are much less so, especially on cognitive functioning. Cognition can be defined as the operations of the human mind and the mental processes that process environmental information, reasoning, thinking, problem-solving, and decision-making. Yet, some data suggest that a sedentary lifestyle may have deleterious consequences on cognition (16).

This hypothesis is supported by embodied cognition approaches that define cognitive functioning as directly grounded in the body and in the current situation (17–19). With a particular interest in sedentary issues, researchers using these approaches have shown that body posture influences the mood of individuals [sad or depressive patients tend to walk slowly and adopt a stooped posture (20)]. More importantly, the amount of energy resources available to a body of an individual changes their perception of the world (21). Tired individuals perceive a hill as being steeper than tired individuals who have just consumed a sweet drink (22). The importance of the body in cognitive functioning is also evident in studies of physical activity. Indeed, regular physical activity has a beneficial impact on cognition (23, 24), mainly on executive functioning (25–27). Executive functions refer to high-level cognitive functions and control processes that occur when the usual courses of action are no longer relevant in a given context (i.e., new, unfamiliar, dangerous, or conflicting situations), thus allowing adaptation of the individual to new situations. Beneficial effects of physical activity are also reported on working memory tasks (28) and at information-processing speed tasks (26, 29). These effects are also reported in normal aging (23, 30), which suggest that physical activity may be a protective factor against aging both in terms of physiological and cognitive functioning.

Accordingly, studies on the effects of sedentarity, outside the context of work, have shown potential negative consequences (16, 31). For instance, time spent watching television is associated with poorer episodic memory capacity (immediate and delayed recall) (4), verbal fluency (4), executive functioning (32), working memory (33), cognitive inhibition (34), and information-processing speed (34) over the long term. These results are extended to children (35) and elderly adults (36). In addition, the amount of objective sedentary behaviors (as measured by the use of accelerometers) and cognitive abilities (37) was found in a longitudinal study (over 2 years) in elderly adults (38). A large cohort study comprising adults aged 37–73 years (31) found a negative association between the amount of self-reported sedentary behaviors vs. working memory and speed of information processing. However, the potential detrimental effects of sedentarity on cognition is not always found [see meta-analysis (39)]. Moreover, it is important to take into account the type of sedentary activity, since time spent watching television and time spent reading (or listening to reading) causes different cognitive effects in young children (40). These correlational studies, outside the context of work, provide initial evidence in favor of the hypothesis that sedentarity has deleterious effect on cognition. Yet, these results are observed for long term sedentary behaviors. It is thus impossible to make a causal link between the production of sedentary behaviors and cognitive alterations since many other lifestyle habits may be involved.

There is also no evidence that sedentary behavior could impact cognition in the short-term. As the consensual definition of a sedentary lifestyle is limited at a specific moment [energy consumption ≤1.5 METs, (5)], it is very unlikely able to capture the potential deleterious consequences of a sedentary lifestyle on cognition. Indeed, in the field of physical activity, regular and prolonged activity is mandatory to observe beneficial effects on different cognitive domains (24, 41–46). In the same way, sedentarity may therefore have little effect on cognition at a specific moment, but only have significant consequences in the longer term. It therefore appears important to distinguish the short term and the long term when the potential cognitive effects of a sedentary lifestyle are considered. It would then be particularly relevant to consider a definition of sedentarity that is not solely "physiological" and makes possible to differentiate sedentary behavior from an individual, or from a sedentary lifestyle (36, 38).

Finally, very few studies are conducted in the context of work (47) whereas sitting for a prolonged period at work is associated with an increased risk of mortality (48). Sedentariness might thus represent a major health issue at the workplace (49), especially in the service industry where workers may remain seated 9–11 h a day (50), and may also be a barrier to efficiency and productivity at work (51, 52). Furthermore, the professional context is an environment in which it is easier to intervene to reduce sedentary behavior since a company can offer standing workstations at relatively low cost and encourage employees to get up regularly. The purpose of this systematic review is then to determine whether sedentarity could impact the cognition of an individual in the context of work.

METHODS

Research Strategies

The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines (53) were used to conduct the research and then to report the data of this systematic review. Published studies on the association between sedentarity and cognition and work were identified and cross-checked by 2 reviewers through a systematic search of the Pubmed, PsycINFO, Cochrane, Web of Science, and Scopus databases. An email alert has also been set up to warn researchers for new articles which might be published online. Articles cited in the selected articles, but not appearing in the databases searched, were also taken into account if they met the eligibility criteria. For this research, articles published between January 1, 2000 and December 31, 2017 were selected. The choice of this time window was motivated by 3 reasons: (1) The study of the sedentary lifestyle has been gaining momentum in recent years; (2) In recent studies, sedentarity is often measured objectively (use of accelerometers), whereas in older studies, it is mainly measured via the use of questionnaires (self-reported measures). In general, participants underestimate the amount of time they spend sedentary (54, 55) because they do not include all the situations they sit in (e.g., watching TV, using a computer, driving, eating); finally, (3) only recent articles distinguish between sedentarity and physical inactivity since sedentarity seems to be an independent factor of physical activity (56), as it has specific health effects (13) independent of those of physical activity (57–61).

Study Selection

To perform this systematic review, the 3 keywords "sedentary" and "cognition" and "work" (and their derivatives) were required to appear in the title or summary (see **Table 1**)[1]. To these 3 keywords were associated, when possible, the filters "English language," "studies on humans," "randomized studies," "academic journals," "between 2000 and 2017," "individuals over 18 years." The choice of the age group (over 18 years) excludes studies with children, but includes persons over 60 [the age at which an individual is considered elderly according to the WHO (63)] that are still engaged in a professional activity. The interest in studies on older people who are still likely to work rests on the hypothesis that a sedentary lifestyle could have an impact on cognitive aging.

Results of the Search

From this research, 4,758 articles were obtained, including 12 from the email alert. After applying the filters, 249 articles were selected, from which 168 duplicates were removed. Of the remaining 81 articles, 42 were not related to the research problem. Of the 39 remaining articles, 26 were not retained because, despite the filters used, one article was about mice, two were about children, two were protocols, two were systematic reviews, two did not take into account the distinction between sedentarity and physical inactivity, one was more interested in the effects of obesity than those of sedentary lifestyles, 10 tested the effectiveness of interventions aimed at reducing sedentary behavior without their effects on cognition, one focused on the antecedents of sedentarity and not on its effects, three were related to retired older adults, and two did not specifically deal with work. Finally, 13 articles remained for the present review (see **Figure 1**).

Data Analysis

In order to determine the methodological quality and validity of the collected studies, the STROBE guidelines (Strengthening the Reporting of Observational Studies in Epidemiology) were used. In addition, the type of population (adults aged 18 and above, and seniors aged 60 and above) were identified. Finally, the experimental intervention or manipulation and the different measurements carried out were noted.

RESULTS

Of the 13 articles included in this review, 10 are randomized cross-over studies (64–73), 2 are randomized not cross-over studies (74, 75) and 1 unclear (76) (see **Figure 1**). The 13 studies selected were divided into three categories: (1) the "short-term" category includes those for which the intervention was performed at one time (64–70, 73, 74); (2) the "medium-term" category includes those for which the intervention took place over several days or weeks (71, 72, 75); and (3) the "long-term" category includes the one for which the intervention took place over several months (76). The characteristics of the selected studies are summarized in **Table 2**.

Measurement of Sedentarity

The presence of a clear and accepted definition of a sedentary lifestyle was sought in the articles to verify the absence of confusion between sedentarity and physical inactivity. However, only 3 articles define sedentarity (71, 74, 76) [all behaviors resulting in energy expenditure $\leq$1.5 METs (5)]. For 2 articles (64, 70), the standard of sedentarity was to remain seated for a long time during the day. In 2 others articles they used a definition

[1]There are articles that can be similar to an intervention against sedentarity in at the workplace, but do not include these keywords. For the sake of rigor, they were not included in this systematic review because assessments of sedentary lifestyles, cognition, and intervention were not necessarily well controlled or reported. It is noteworthy, however, that the results of these studies are in line with those reported in this systematic review [see (62) for a review of active workstations].

TABLE 1 | Search strategies applied in order to select studies.

PubMed	PsycInfo	Cochrane	Scopus	Web of science
Cognit* AND Sedentary AND Work*	Cognition (Explode) AND Sedentary (Major Concept)	Cognit* AND Sedent* AND Work* (Title/Abstract)	Cognit* AND Sedent* AND Work* (Title/Abstract)	Cognit* AND Sedent* AND Work* (Title/Abstract)
Cognit*AND Sedentary AND Work	Cognition (Explode) AND Sedentary AND Work	Cognition AND sedentary AND work*	Cognition AND sedentary AND work*	Cognition AND sedentary AND work*
Cognit* AND Sedentary (Title/Abstract)	Cognit* AND Sedentary AND work*	Cognit* AND Sedentary AND Work*	Cognit* AND Sedentary AND Work*	Cognit* AND Sedentary AND Work*

based on the accelerometers (75, 76). Finally, for 8 articles (65–69, 71–74), the criteria for sedentary were not indicated (see **Table 2**).

Sedentarity was assessed by accelerometers and self-reported measures in four studies (64, 72, 73, 75), only by self-reported measures in 4 studies (65, 66, 70, 74) and only by accelerometers in 2 studies (71, 76). For the last 3 studies (67–69), sedentarity was neither assessed nor reported. Solely accelerometers allow an objective and sensitive measurement of the amount of sedentary behavior.

Cognitive Functions Tested

The cognitive functions tested were cognitive flexibility (64, 72, 73, 76), cognitive inhibition (64–68, 70, 72–74), working memory (67, 71–76), episodic memory (70), memory short-term (65, 72), reasoning (68, 69, 71, 73, 75), sustained attention (66, 70, 72, 75), planning (75), information processing speed (65, 66, 68, 70, 72, 74), and psychomotor function (71) (see **Table 3**). Most of the functions tested involve attentional processing and/or executive control. This choice is probably justified by the fact that physical activity preferentially improves these functions (23, 41, 111, 112).

Age of Participants

On the 13 articles selected, 9 studies were conducted among adults aged 18–50 (64, 66–70, 73–75), 1 with adults aged 18–58 (71), 1 with adults aged 23–60 (65) or between the ages of 22 and 62 (72). Finally, 1 study was conducted among people aged between 60 and 79 years (76). In 2 studies, the range of the age's participants was homogeneous (66, 75) and in 5 other studies age was controlled as a co-variable (65, 67, 71, 73, 76).

Main Results

In the selected studies, two types of paradigms were used: (1) one was to compare the achievement of a cognitive task either sedentarily (sitting in a traditional office) or while performing or just after completing light or moderate physical activity (through the use of dynamic workstations or while working standing) (64–74); (2) the other compared cognitive performance with different tests of physically active individuals to that of sedentary individuals and without using a dynamic workstation during testing (75, 76).

Studies Involving the Use of Dynamic Workstations

Adults working on a treadmill desk (64, 65, 67, 68, 70, 73, 74), or on an elliptical trainer (74), or on a cycling desk (69, 70, 74) do not perform better than those working at a traditional desk, whether for tasks of cognitive inhibition (64, 65, 67, 68, 70, 73, 74), speed of information processing (70, 74), working memory (67, 73, 74), episodic memory (70), short-term memory (65), sustained attention (70), cognitive flexibility (64, 73), or reasoning (69, 73). Similarly, when the participants have to alternate between sitting and standing (66, 72), no difference is observed with tasks of cognitive flexibility, cognitive inhibition, working memory, short memory, sustained attention, and speed of information processing. Reversely, adults working at a treadmill desk perform worse on reasoning (68) and processing speed (65, 68) tasks than adults working at a conventional desk, but after short periods of physical activity (e.g., walking, standing, pedaling), overweight adults perform better on a working memory, psychomotor and reasoning tasks than when they sit without physical activity (71).

Studies That Do Not Involve the Use of Dynamic Workstations

Replacing sedentary behaviors for 6 months through moderate physical activity in older people improve their performance at working memory and cognitive flexibility tasks (76). Using a reverse principle, adults forced to remain inactive for a week do not show modified performance on working memory, reasoning skills, planning skills, or concentration (75).

DISCUSSION

The purpose of this systematic review was to identify the potential effects of work-related sedentariness on cognitive functioning. While the effects of sedentarity on physical health are now established (2, 3, 113), the impact on psychological health and cognitive abilities remains uncertain (16). Increasing sedentary behavior at the workplace is a major public health issue and a particularly relevant choice because of (1) the importance of time spent working per day; (2) the possibility of controlling this environment (and therefore intervening for workers); and (3) the economic and health implications of possible cognitive changes due to sedentary productivity (in the short term) and the risk of cognitive decline (in the long term) of the workers concerned. This distinction is equivalent to seeking the effects of sedentary behavior regardless of an individual's lifestyle ($\leq$1.5 METs at a given time), a predominantly sedentary lifestyle (36, 38). Thus, as highlighted in the introduction, we should distinguish on the one hand longitudinal or correlational studies that are intended to

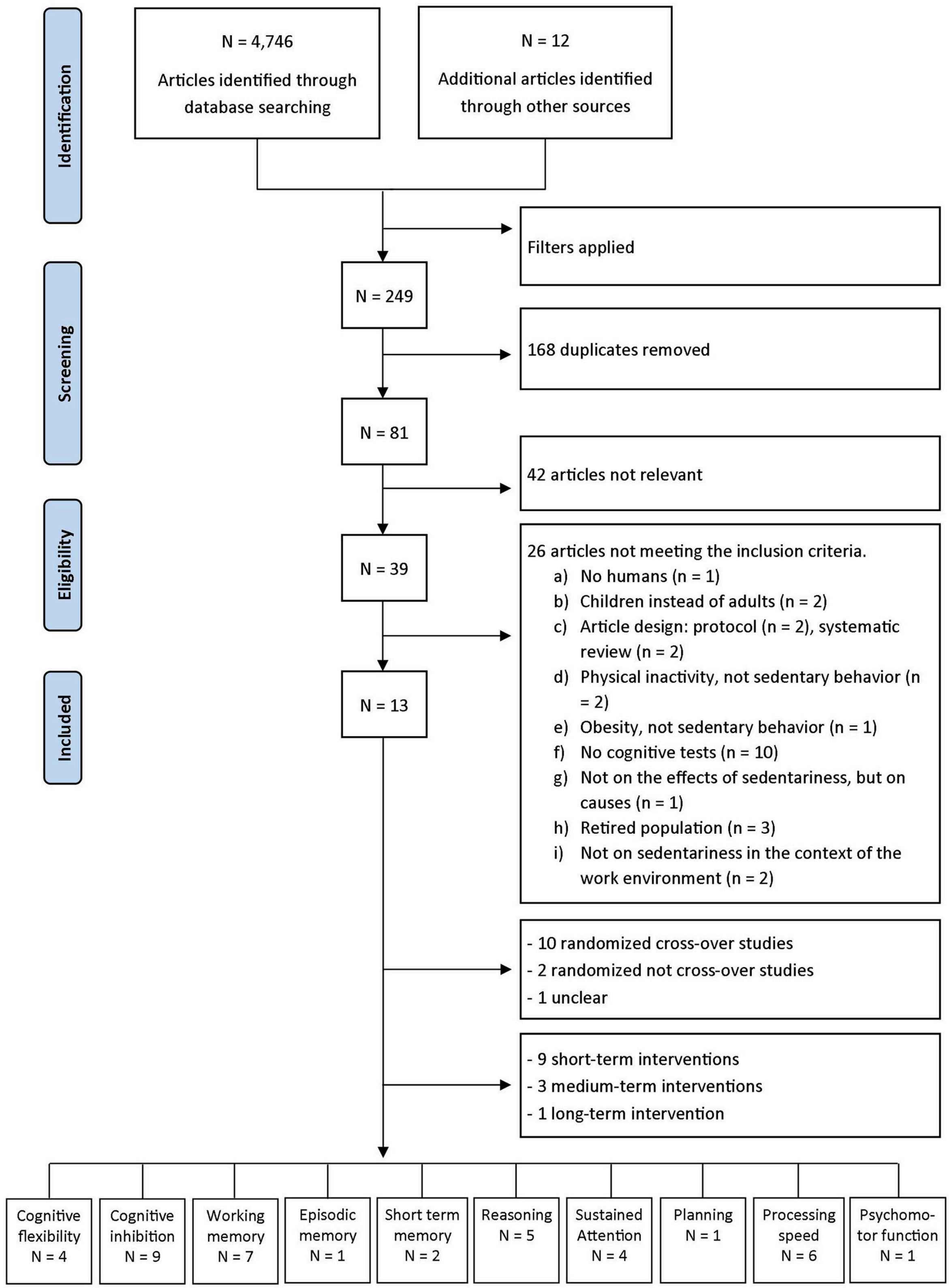

FIGURE 1 | Flow chart of the steps followed in the systematic review (several cognitive tests may have been used in the same article).

TABLE 2 | Characteristics of selected studies.

Articles and study design	Stobe score	Mean age (SD) [*Range*]	Population	Intervention/*Cognitive functions tested*	Type of intervention	Sedentariness: type of measures/*Definition*	Main results
SHORT-TERM STUDIES							
Alderman et al. (67) Randomized cross-over	23	21.06 (1.6) (17–24)	Undergraduate students. *N* = 66	2 conditions: Treadmill-desk *vs.* Seated condition. Cognitive inhibition/Working memory	Short-term intervention: 2 conditions separated by 48 h.	NA.	No differences.
Bergouignan et al. (64) Randomized cross-over design	25	30 (5.6) (24–49)	Sedentary adults. *N* = 30	3 conditions: 6 h of uninterrupted sitting (SIT) vs. SIT plus 30 min of moderate-intensity treadmill walking vs. SIT plus six hourly 5-min microbouts of moderate-intensity treadmill walking. Cognitive flexibility/Cognitive inhibition	Short-term intervention: 1 condition per day (about 10 h).	Physical activity and sedentariness measured by a questionnaire [*International Physical Activity Questionnaire*, (77)] and by an accelerometer worn for 1 week. Sedentary if participants self-report sitting more than 9 h/day.	No differences.
Commissaris et al. (74) Randomized repeated measures design	24	29 (12) [>18]	Adults. *N* = 15	6 conditions: Treadmill desk vs. Elliptical trainer vs. Bicycle ergometer (2 conditions) vs. Standing workstation *vs.* Standard sitting position. Cognitive inhibition/Working memory/Information processing speed	Short-term intervention: 1 condition per full working day (7/8 h).	Physical activity practiced self-reported.	No differences.
Ehmann et al. (73) Randomized cross over	24	**Young adults**: 20.6 (2.0) (17–27) **Middle-aged adults**: 45.6 (11.8) (30–64)	Young adults: *N* = 32 Middle-aged adults: N = 26	2 conditions: Treadmill walking (low intensity) vs. Seated control condition. Cognitive flexibility/Cognitive inhibition/Working memory/Reasoning	Short term intervention: 2 experimental conditions, each separated by at least 48 h.	Physical activity self-reported [*physical activity readiness questionnaire*, (78)] and measured by an accelerometer wore during test sessions.	No differences.
John et al. (68) Randomized cross-over	22	26.4 (4.04) [NC]	Graduate students. *N* = 20	2 conditions: Treadmill desk vs. Sitting. Cognitive inhibition/Reasoning/Information processing speed	Short-term intervention: 2 visits of 60 minutes separated by 2 days; 1 condition/day.	NA.	Poorer performances on reasoning and information processing speed in the treadmill desk condition.
Ohlinger et al. (65) Randomized cross-over	20	43.2 (9.3) (22–59)	Employees of Miami University. *N* = 50	3 conditions: Sitting vs. Standing vs. Walking. Cognitive inhibition/Short term memory/Information processing speed	Short-term intervention: A single 75-min visit.	Physical activity and sedentariness measured by questionnaire (hours spent sitting at work each day, and number of days they exercise each week).	No differences other than a decrement on the processing speed task during walking compared to sit and stand.

(Continued)

TABLE 2 | Continued

Articles and study design	Stobe score	Mean age (SD) [*Range*]	Population	Intervention/*Cognitive functions tested*	Type of intervention	Sedentariness: type of measures/*Definition*	Main results
Pilcher and Baker (69) Randomized cross-over	21	19.64 (1.05) [NC]	Undergraduate students. *N* = 38	2 conditions: Cycling vs. Sitting at a traditional desk. Reasoning	Short-term intervention: Two 45-min sessions separated by 24 h at least.	NA.	No differences.
Schwartz et al. (66) Randomized cross-over	25	25.4 (3.3) (19–31)	Students. Control group (*n* = 15) Experimental Group (*n* = 30) *N* = 45	Control group: Sitting for 5 consecutive 30-min trials each. Experimental group, 2 conditions: Alternate sitting and standing postures every 30 min. 5 times *vs.* sit for 5 trials. Cognitive inhibition/Sustained attention/Information processing speed	Short-term intervention: 2 whole days separated by 7 days; 1 condition per day.	Physical activity and sedentariness measured by a questionnaire [*International Physical Activity Questionnaire*, (77)].	No differences.
Torbeyns et al. (70) Randomized cross-over	23	35.7 (10.3) [NC]	Adults with a sedentary occupation. *N* = 23	2 conditions: Cycling desk vs. Sitting on a conventional chair. Cognitive inhibition/Episodic memory/Sustained attention/Information processing speed	Short-term intervention: 2 visits separated by 1 week; 1 condition per visit.	Physical activity practiced self-reported [*International Physical Activity Questionnaire*, (77)]. Sedentariness if the individual is seated for at least 70% of the workday.	No differences.
MEDIUM-TERM STUDIES							
Edwards and Loprinzi (75) Randomized controlled, parallel group intervention	27	21.74 (2.82) (17–34)	Adults. Control group (*n* = 10). Experimental group (*n* = 23). *N* = 33	Control group: Normal practice of physical activity. Experimental group: Reduce physical activity as much as possible for a week. Working memory/Reasoning/Sustained attention/Planning	Medium-term intervention: reduction of physical activity during 1 week.	Physical activity practiced and sedentariness self-reported by a questionnaire [*International Physical Activity Questionnaire*, short form, (77)] and wearing an accelerometer for 1 week prior to the intervention and wearing a pedometer during 7 days. Sedentariness if no practice of structured physical activity and less than 5,000 steps a day.	No differences.
Mullane et al. (71) Randomized cross-over full-factorial design	24	30 (15) (17–57)	Overweight adults with a sedentary office-based occupation. N = 9	4 conditions: Sit vs. Sit-Stand *vs.* Sit-Walk *vs.* Sit-Cycle. Working memory/Reasoning/Psychomotor	Medium-term intervention: Each condition performed across 4 consecutive weeks, 7 days apart.	Physical activity and sedentariness measured by an accelerometer.	Improved working memory, reasoning and psychomotor if short moments of light physical activity (standing, walking, cycling).
Russell et al. (72) Randomized cross-over	24	40.08 (11.93) (21–61)	Employees of the university of Tasmania. *N* = 36	2 conditions: Sitting vs. Standing (or the reverse) for 1 h per day for 5 consecutive days. Working memory/Sustained attention/Information processing speed/Cognitive flexibility/Cognitive inhibition/Short-term memory	Medium-term intervention: 1 h/day for 5 consecutive days.	Physical activity and sedentariness measured by a questionnaire [Occupational Sitting and Physical Activity Questionnaire, (79)] and by an accelerometer.	No differences.

(Continued)

TABLE 2 | Continued

Articles and study design	Stobe score	Mean age (SD) *[Range]*	Population	Intervention/*Cognitive functions tested*	Type of intervention	Sedentariness: type of measures/*Definition*	Main results
LONG-TERM STUDY							
Fanning et al. (76) Unclear	25	65.4 (4.6) (59–78)	Older people among whom 120 still have a professional activity. $N = 247$	3 conditions: Substituting 30 min of sedentary behavior with 30 min of (a) light activity, (b) moderate-to-vigorous physical activity, or (c) sleep. Cognitive flexibility/Working memory	Long-term intervention: during 6 months.	Sedentariness measured by accelerometer during 7 consecutive days. Sedentariness if number of counts per minute at the accelerometer is <50.	Better performances.

NA, Not Available; sedentarity was not defined, and not assessed or reported.

TABLE 3 | Cognitive functions measured, and tests used in the selected articles.

Cognitive functions	Tests	Authors
Cognitive flexibility	Trail Making Test (TMT) (80)	(64, 72)
	Wisconsin card sorting test (81)	(73)
	Task switching paradigm (82)	(76)
Cognitive inhibition	Stroop and their derivatives (83)	(65–68, 70, 72, 73)
	Go-No-Go (84)	(74)
	Flanker task (85)	(64, 67, 74)
Working memory	N-back (86)	(71, 74)
	Spatial span (87)	(75)
	Digit span subtest	(72)
	Sternberg working memory task (88)	(73)
	Scholastic assessment test (SAT) (89)	(67)
	Paired associates (90)	(75)
	Spatial working memory task (91)	(76)
	Letter Number Sequencing subtest (LNS) (92)	(72)
Episodic memory	Rey auditory verbal learning test (93)	(70)
Short term memory	The auditory consonant trigram test (94)	(65)
	Digit span subtest (92)	(72)
Reasoning	Grammatical reasoning (95)	(75)
	Graduate record examination (96)	(68)
	Tower of London (97)	(73)
	Set-shifting test (98)	(71)
	Odd one out (95)	(75)
	Law School Administration Test (LSAT) (99)	(69)
	Raven's standard progressive matrices (100)	(69)
Sustained attention (concentration)	Feature match (101)	(75)
	Polygon (90)	(75)
	Four-choice visual reaction time test (CRT) (102)	(72)
	d2R (103)	(66)
	Rosvold Continuous Performance Test (RCPT) (104)	(70)
Planning	Spatial search (105)	(75)
	Spatial slider (106)	(75)
Information processing speed	Typing task (107)	(68, 70, 74)
	Fast counting task (108)	(74)
	The Digital Finger Tapping test (DFTT) (109)	(65)
	Digit Symbol Coding subtest (DSC) (92)	(72)
	Trail Making Test (TMT) (reaction time) (110)	(72)
	Stroop (reaction time) (83)	(70)
	Rosvold Continuous Performance Test (reaction time) (104)	(70)
	Transcription test	(70)
	Text editing task	(66)
Psychomotor function	The detection test (98)	(71)

determine the existence and factors of the possible repercussions of sedentarity on cognitive health, and on the other hand, studies and interventions whose objective is the reduction of sedentary behaviors. The filters applied for this systematic review resulted in only interventional studies. Among them, it seems still relevant to distinguish the studies according to the duration of the intervention: in the short term, medium term, and long term.

Summary of the Main Results

The results, taken as a whole, appear contradictory. Four studies (65, 68, 71, 76) among the 13 identified highlight a significant change in cognition related to sedentary behavior. Of these 4 studies, 2 (71, 76) show an improvement in cognitive performance when sedentary behavior is decreased, but two shows deterioration (65, 68).

These contradictions do not seem to be explained by the type of intervention employed. Of the 11 studies involving the use of a workstation (64–74), 8 (64, 66, 67, 69, 70, 72–74) found no alteration of cognitive functions, one (71) reports an improvement in performance to a task of working memory, psychomotor functions and reasoning, while the last 2 (65, 68) report a drop in performance at a task of reasoning (68) and speed of information processing (65, 68) when using a treadmill desk (but not at a task of cognitive inhibition). The cognitive function considered also does not seem to be able to explain these contradictions, since, out of all the studies included, 2 report beneficial effects on working memory (71, 76) while others report no effect on the same function (67, 72, 74, 75).

The distinction between short-term, medium-term and long-term intervention, on the other hand, offers a different interpretation. No short-term and medium-term interventions report a significant improvement in cognitive functioning when measures are taken to decrease sedentary behavior, with the exception of one study that targets overweight individuals, thus limiting possible generalization of this result (71). On the contrary, two of the short-term interventions show a decrease in performance (65, 68); these studies were the only two to not offer a familiarization session that allowed participants to adapt to the use of the dynamic workstation. This result could then be explained by a dual-task situation (114). The results reported by these two studies are a decrease in performance at reasoning tasks (68) and speed of information processing (65, 68) but not for tasks of cognitive inhibition (65, 68) and memory in the short term (65) when using a treadmill at the same speed (1.6 km/h). It is therefore possible that this dual-task situation affects information processing and reasoning tasks because the former could be more costly with regard to motor skills and the second cognitively more costly than the other tasks. The only long-term study identified in this systematic review (76), however, suggests a beneficial effect on the cognitive functioning of people with a less sedentary lifestyle and work.

Among the few cognitive functions tested, significant results are observed for working memory (71, 76), reasoning (71), psychomotor function (71), and mental flexibility (76). These observations are consistent with the effects of physical activity on cognition (23, 24, 41, 82).

Explanatory Hypotheses of Divergent Results

These seemingly contradictory results lead us to consider 5 factors to be taken into account in the study of the possible effects of sedentarity on cognition.

1. **Duration of the intervention or duration of the sedentarity.** These durations should be controlled as the effects of sedentarity on cognition may stem from the chronic processes observable only over the long term.
2. **Daily physical activity.** Regular physical activity may be sufficient to have a protective effect on cognitive functioning, making the effects of sedentary lifestyles invisible (75).
3. **Testing time.** The timing of the testing, i.e., during physical activity, immediately after or in the longer term appears to impact differently the results. Testing cognitive functions during physical activity may test more divide attentional abilities than not being sedentary (114) especially when no familiarization session is provided [see (65, 68)].
4. **Age of the participants**. Chronic sedentary effects are more likely to be apparent in older individuals than in younger individuals. In addition, as advancing age is associated with cognitive decline (115), the effects potentially observed in older sedentary individuals must be age-controlled (matched control group) as it is the case for only 7 of the 13 studies included here (65–67, 71, 73, 75, 76).
5. **Measure of sedentarity**. How sedentarity is measure may impact the results because subjective measures (questionnaires) [see (83, 86, 111, 112)] may underestimate the amount of time spent sedentarily (54, 55).

Recommendations

This systematic review of the literature has highlighted the lack of studies on the consequences of sedentariness on cognitive functioning at work. The data mainly not showed any significant results. Nevertheless, such a link is predicted by embodied cognition approaches (18, 19, 21) and is supported by studies of the effects of physical activity on cognition (23, 24). It would seem, then, that the chronicity of the behaviors is the determining factor. To answer these problems, it appears essential to follow various recommendations. A first action would consist in determining if sedentary behaviors can have an impact on cognitive functioning. To do this, retrospective, longitudinal, or epidemiological studies should be conducted. These studies should propose: (1) questionnaires or objective measures assessing the importance, frequency and duration of sedentary behavior, making sure to distinguish whether these behaviors occur at work or not; (2) objective questions or measurements of physical activities performed; and (3) a cognitive assessment, if possible exhaustive, or at least targeting working memory, executive functions, and the speed of information processing. It would then be possible to determine to what extent sedentarity at work, in relation to sedentary life outside of work and physical activity, makes it possible to explain the cognitive functioning of an individual by controlling for age, sex, level of education, and other protective or risk factors of cognition (sleep apnea, cognitive reserve, etc.).

If the results prove significant, then it will become relevant to set up interventional studies. Beyond the fact that these studies should favor a randomized plan with a random distribution of participants in each experimental condition, they could also follow the 8 recommendations bellow organized in order of importance.

1. **Duration of the intervention.** Short interventions are ineffective in showing a positive effect on cognitive functioning, at least in the general population [but see (71) for overweight people], but they are in the long term [see (88)]. This last study is the only one to propose an intervention over 6 months. However, work on physical activity suggests that effects can be seen as early as 4 weeks of intervention (116).
2. **Baseline.** Since measuring the effectiveness of an intervention requires comparing performance before and after the intervention, it is necessary to choose tests that are not very sensitive to the test-retest effect, or to include a control group that does not benefit from any intervention.
3. **Tests.** The cognitive tests used must be valid, reliable, and sensitive. The use of standardized tests commonly recognized among researchers in cognitive psychology or neuropsychology is recommended. Moreover, and ideally, a cognitive function should be evaluated by two different measures (117). In the case of an intervention involving the use of dynamic workstations, it is important to consider when the participants are cognitively assessed (before, during or after physical activity). If the cognitive test is administered while performing physical activity, it is important to consider the degree of habituation of participants to work while doing physical activity. Familiarization sessions are therefore recommended (70).
4. **Measurement of current sedentarity**. Objective measures of sedentary behavior should be favored with, for example, the use of accelerometers (16, 38).
5. **Physical activity and previous sedentary lifestyle.** It also seems essential to assess the level of physical activity of the participants (current and previous) and the previous level of sedentarity of the participants, since they could have long-term effects on the cognitive health of individuals.
6. **Homogeneity of population**. The target population should be as homogeneous as possible to control for the possible influence of variables such as socio-economic level or age group of participants. Moreover, since the professional activity that requires a regular elaborated cognitive engagement seems to have a protective effect on cognitive decline (118), it is also recommended to take into account the activities carried out in the context of work.
7. **Specificity of effects of the intervention.** The specifics of the type of intervention should ideally be controlled to determine whether it is the intervention itself that produces an effect and not other factors combined (such as simply participating in a study or changing the season). This specificity could be tested by including a group benefiting from an intervention with no expected effect on the sedentary lifestyle (e.g., speech group).
8. **Maintaining effects over time.** Finally, it is particularly interesting to know the maintenance of the effects after the intervention, which can be done by including measures several months after the end of the intervention relating not only to the cognitive functions, but also to the maintenance of the practices used to reduce the sedentary lifestyle.

Limitations

Several limitations must be considered when interpreting these findings. There may be a publication bias which limits generalizability of our findings; however, this limitation is inherent in all systematic reviews. Indeed, the review was limited to peer-reviewed published work and to the search terms and databases contained in our Methods section. Studies that have not been abstracted with these key words are inevitably missing from the review, but we also searched the cited works in each selected article. Our search strategy was also limited to English-only studies, which may have resulted in a language and cultural bias. In addition, the heterogeneity in methods among the studies—such as the use of different cognitive tests as well as the small sample sizes—, and the small number of papers that fulfilled the inclusion criteria, have to be accepted as necessary due to the infancy of this field of research on sedentary behavior and cognition at the workplace.

CONCLUSION

Effects of work-related sedentarity on cognition appear mixed. Most of the studies do not report significant results on cognition, but other psychological consequences such as a decrease in the feeling of tiredness (64), an increase in motivation (69), and a more positive mood (64) [see also (119)] are nevertheless observed. The psychological repercussion of sedentariness may be better explored by considering sedentarity no longer through the physiological definition [$\leq$1.5 METs, (5)], but through a psychological definition referring to the prospective cognitive consequences of this way of life (120–123). It is also important to manipulate the production of sedentary behaviors instead of the practice of activities, as it was the case in most of the included studies.

Although chronic sedentary lifestyles and physical inactivity share many similarities, the distinction between these two concepts is fundamental. Thus, intervention for physical inactivity focuses on the establishment of sports activities that is usually done during leisure time. On the other hand, interventions to combat a sedentary lifestyle do not require a sporting activity, since simply standing can be enough to counteract the physiological effects of a sedentary lifestyle (8–10). This particularity makes it possible to intervene not only on the leisure time of an individual, but also on his or her time and place of work. It seems much simpler to suggest a person to get up regularly or to work while standing than to go for a 15-min run during a break. Health preventive programs may then propose work adaptation such as broadcast a signal to encourage the workers to get up every 20 min or suggest the use of standing desks or active workstations whenever possible.

Finally, more information about the consequences of sedentarity on both physical and psychological health should be available to the workers and to the structures.

AUTHOR CONTRIBUTIONS

VM reviewed the literature, revised CA's article outline, created and maintained a Zotero database, wrote the initial abstract, manuscript, and table and figure drafts, and revised the second drafts following feedback from CA. CA reviewed the literature, and proposed an article outline. Both CA and GV contributed sections of the initial drafts, and made editorial suggestions for the second drafts. VM, CA, and GV discussed the conceptual issues and themes for the review article. All authors contributed to manuscript revision, read and approved the submitted version.

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Sedentariness and Health: Is Sedentary Behavior More Than Just Physical Inactivity?

Shirin Panahi[1,2] *and Angelo Tremblay*[1,3]*

[1] Department of Kinesiology, Université Laval, Québec City, QC, Canada, [2] Department of Physical Education, Université Laval, Québec City, QC, Canada, [3] Centre de Recherche de l'Institut de Cardiologie et de Pneumologie de Québec, Québec City, QC, Canada

Sedentary behavior refers to certain activities in a reclining, seated, or lying position requiring very low energy expenditure. It has been suggested to be distinct from physical inactivity and an independent predictor of metabolic risk even if an individual meets current physical activity guidelines. Over the past decades, a shift in the activity profile of individuals has been observed with vigorous physical activity and sleep being partly replaced by cognitive work, a potential neurogenic stress component considering its hormonal and neurophysiological effects, leading to various impacts on health. Mental work, for instance, may significantly increase glycemic instability leading to an increase in the desire to eat and thus, higher energy intakes. Furthermore, screen-based leisure activities (e.g., television watching) and screen-based work activities (e.g., computer use for work purposes) have often been considered together while they may not trigger the same stress response and/or use of substrate. Thus, the problems of sedentariness may not only be attributed to a lack of movement, but also to the stimulation provided by replacing activities. The objective of this review is to discuss the (1) recent evidence and current state of knowledge regarding the health impact of sedentary behaviors on health; (2) potential neurogenic effects of cognitive work as a sedentary behavior; (3) link between sedentary behaviors and the diet; (4) resemblance between sedentary behaviors and the inadequate sleeper; and (5) potential solutions to reduce sedentary behaviors and increase physical activity.

Keywords: sedentary behavior, mental work, diet, physical inactivity, sit-stand desks, exercise pause, physical activity participation

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Frederic Dutheil,
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Audrey Bergouignan,
UMR7178 Institut Pluridisciplinaire Hubert Curien (IPHC), France
Felipe Barreto Schuch,
Universidade La Salle Canoas, Brazil

Correspondence:
Angelo Tremblay
angelo.tremblay@kin.ulaval.ca

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INTRODUCTION

Although the beneficial health effects of physical activity have been well recognized, physical inactivity accounts for 9% of premature mortality worldwide (1). The term physical inactivity refers to performing insufficient amounts of moderate to vigorous-intensity activity (i.e., not meeting specific physical activity guidelines) (2). Sedentary behavior, on the other hand, has been suggested to be distinct from physical inactivity and an independent predictor of metabolic risk even if an individual meets current physical activity guidelines (3). The World Health Organization recommends that adults aged 18 or older participate in at least 150 min of moderate-to-vigorous activity per week or the equivalent of 30 min of daily activity (4). Currently, just over 15% of Canadian adults are meeting these guidelines (5). However, it is unclear if meeting these guidelines of activity is sufficient to be considered non-sedentary. Daily physical activity levels are evaluated by a person's daily energy expenditure divided by his or her basal metabolic rate (6). The prevalence of sedentary behavior, defined as any waking behavior that requires low energy expenditure ($\leq$ 1.5 MET) such as prolonged sitting, reclining or lying down (2), is very high in developed countries. Results from the 2003/2004 National Health and Nutrition Examination Survey (NHANES) demonstrated that children and adults in the United States spend ~7.7 h/day of their waking time engaged in sedentary behaviors such as watching television, playing passive video games, using the computer, prolonged sitting (e.g., at a desk) and motorized transportation (7).

Over the last 30 years, overweight and obesity have become characteristic of the majority of Canadians which has led to a concomitant increase in the prevalence of co-morbidities including type 2 diabetes and cardiovascular disease. Sedentary behavior has been a contributing factor to this epidemic and associated with an increased risk of all-cause mortality (8, 9). In a 12-year prospective study, a progressively higher risk of mortality was found across higher levels of sitting time from all causes and cardiovascular disease, independent of leisure-time physical activity (10). Furthermore, in a meta-analysis of six studies evaluating daily sitting time and all-cause mortality, a 34% higher mortality risk for adults sitting 10 h/day was observed after taking physical activity into account (9). Sedentary behavior has also been linked with poor glycemic control including a reduction in insulin sensitivity and glucose uptake (11). Several animal studies have shown that insulin-mediated glucose uptake is significantly reduced due to muscular inactivity (12, 13). Epidemiological studies have consistently reported that time spent in sedentary tasks that require little muscular activity (low accelerometry counts, computer use or self-reported television time) is negatively associated with insulin action (14, 15). In a clinical trial, healthy non-exercising young men who reduced their daily activity levels from normal (10,501 steps/day) to low (1,344 steps/day) levels of ambulatory activity for 2 weeks were found to display metabolic alterations including a 17% decline in their insulin sensitivity (16). However, because higher inactivity decreases energy expenditure, if this reduction is not compensated for by a reduction in energy intake it will lead to energy surplus which has been shown to increase insulin resistance (17).

In addition to the changes in human activity, globalization and technological changes have favored a progressive switch from physically demanding tasks to knowledge-based work or mental activity soliciting an enhanced cognitive demand. Screen-based leisure activities (e.g., television watching, video games, and internet use) and screen-based work activities (e.g., computer use for work purposes) have often been considered together while they may not trigger the same stress response and/or use of substrate. Furthermore, from a physiological perspective, the biological requirements and effects of physical and cognitive work are not the same. Mental work, for instance, may significantly increase glycemic instability (i.e., wide fluctuations in blood glucose concentrations) leading to an increase in the desire to eat and thus, higher energy intakes (18, 19). Thus, the problems of sedentariness may not only be attributed to a lack of movement, but also to the stimulation provided by replacing activities. In a context where there is exposure to cognitive work, novel strategies to increase physical activity and improve energy balance regulation are needed.

Therefore, the objective of this review is to discuss the (1) recent evidence and current state of knowledge regarding the health impact of sedentary behaviors on health; (2) potential neurogenic effects of cognitive work as a sedentary behavior; (3) link between sedentary behaviors and the diet; (4) resemblance between sedentary behaviors and the inadequate sleeper; and (5) potential solutions to reduce sedentary behaviors and increase physical activity.

EPIDEMIOLOGICAL OBSERVATIONS

The energy cost of various activities, both in work and leisure, has been of great interest to researchers. Regular physical activity has been associated with decreased adiposity (20, 21), an increase in muscle oxidative potential (22) and resting metabolism (21), a decrease in energy intake relative to energy expenditure (23) and an increase in beta-adrenergic stimulation (21, 24). In a study examining the association between physical activity and weight loss maintenance in a group of individuals who were previously living with obesity, participants in the highest tertile of physical activity (highly active; >1575 kcal/week) experienced a significantly lower weight regain compared to those in the low (<850 kcal/week) and moderately (850–1575 kcal/week) active groups after a two year follow-up (25). This suggests that significant weight loss may be maintained for 2 years when weekly caloric expenditure is greater than 1500 kcal/week; however, success also depending upon the degree of lifestyle changes made. This study also indicated that the increasing the frequency of exercise appeared to be the best method for increasing weekly caloric expenditure and that increased fat utilization post-exercise may be a likely contributor to maintaining a lower body weight long term. Inverse associations have been observed between time spent in moderate-to-vigorous physical activity and indices of adiposity in children, independent of objectively measured sedentary time and other covariates, while sedentary behavior was not linked with any of the adiposity indicators (26). However, frequent interruptions in sedentary time have been shown to be associated with a favorable cardiometabolic risk profile in adults (27) and among children with parental obesity (28). In a cross-sectional study of children with a family history of obesity, examining the associations among moderate-to-vigorous physical activity, fitness, sedentary behavior and insulin sensitivity using two markers of characterization (i.e., accelerometer and screen-time), it was found that physical activity was correlated with indices of insulin sensitivity independent of fitness and sedentary behaviors; however, this association was attenuated when adiposity was considered (29). Furthermore, self-reported screen-time was negatively associated with insulin sensitivity in girls, but not boys, after controlling for physical activity, fitness and adiposity (29). Although the reason for this is not clear, other factors including dietary habits linked to screen-time were suggested to be involved which may explain its effects on insulin sensitivity (29). Additionally, as previously discussed, this suggests that a stress-related biological reality related to screen-time may also promote metabolic dysfunctionality. In a recent meta-analysis of 16 studies, high levels of moderate intensity physical activity (60–75 min/day) appeared to offset the increased risk of mortality associated with high sitting time; however, the high activity did not eliminate the increased risk associated with television viewing suggesting the importance of considering the type of activities while sitting (30).

Extended periods of sedentary behavior results in low energy expenditure and may contribute to weight gain and negative health effects via effects on energy intake. Changes in energy expenditure and energy intake have been attributed to many factors including changes in family dynamics and popular sedentary activities including using computers and television viewing. In a systematic review of observational studies, higher levels of sedentary behavior (e.g., television viewing) were associated with a less healthful diet, such as less fruit and vegetable intake and higher consumption of energy-dense snacks and sugar-sweetened beverages in pre-school and school-aged children and adolescents (31). However, the results were less conclusive in adults. Technological development has favored a progressive switch from physically demanding tasks to knowledge-based work, soliciting great cognitive demand (32). This may be reflected by activities such as computer "chatting" in children, whereas for adults, it may represent knowledge-based work that appears to be essential from the perspective of economic competitiveness (i.e., labor efficiency and productivity) (33).

EFFECTS OF SEDENTARY BEHAVIOR VS. PHYSICAL INACTIVITY ON ENERGY INTAKE, APPETITE CONTROL AND METABOLISM

Over time, a shift in the activity profile of individuals has been observed. Vigorous physical activity and sleep have been, in part, replaced by cognitive work which has also contributed to various health-related effects. Sedentary occupations have become the norm with approximately one in two individuals performing primarily sedentary tasks. In addition to the low energy expenditure from these sedentary tasks, high mental demands at work have been associated with increased food intake suggesting that this may lead to a positive energy balance (34–36). In a study examining the impact of knowledge-based work on spontaneous energy intake, subjective appetite and glucose homeostasis, healthy women students were randomly assigned to one of three 45-min conditions including (1) resting in a seated position; (2) reading a document and writing a summary; or (3) performing a battery of computerized tests followed by an *ad libitum* buffet meal (18). Although no differences in subjective appetite were observed, mean energy intake following the reading-writing and automated test-battery conditions exceeded that measured after rest by 203 kcal and 253 kcal, respectively (18). Furthermore, significant variations in plasma glucose and insulin concentrations were observed compared to the seated only position suggesting that this may be considered a risk factor for a positive energy balance leading to overweight in the longer term (18). Cortisol concentrations over the 45 min in the two cognitive conditions was also significantly higher compared to the control condition suggesting knowledge-based work as a neurogenic stress component considering its hormonal and neurophysiological effects. Activation of the hypothalamic-pituitary-adrenal (HPA) axis is the primary neuroendocrine response to both psychological and physiological stress and previous studies (37, 38) have shown that stress-induced cortisol reactivity is associated with greater food intake which may explain the response to the knowledge-based conditions in this study (18). In another study assessing the impact of a major work deadline (high workload) and a quiescent period of work (low workload) on plasma lipids, dietary intake, and self-reported stress in employees, self-reported stress, plasma total cholesterol, energy and dietary fat intakes were higher in the high workload compared to the low workload condition (34). Although the association between cognitive work and body weight has been primarily investigated in adults, one study examining the link between homework duration, adiposity indicators, and stress-related levels in school-aged children found that boys with a high workload of homework, when combined with schoolwork-related stress, had unfavorable adiposity indicators (i.e., higher percent body fat) (39). As has been previously suggested, from a physiological perspective, the biological requirements of physical and mental work are different because knowledge-based work is a type of activity that relies on the brain which utilizes glucose for the metabolism of energy compared to physical activity which uses skeletal muscle and relies mostly on fat metabolism, depending on the type of physical activity (40). For example, frequent interruptions of prolonged sitting with short bouts of activity rely primarily on carbohydrate as fuel. However, in a study by Volkow et al., positron emission tomography was used to examine the impact of methylphenidate medication on the amount of glucose required by the brain to perform a cognitive task (41). It was found that methylphenidate reduced the increase in carbohydrate utilization induced by mental work by ∼50% (41).

Appetite control occurs through a complex interaction between physiology and behavior. Low physical activity levels have been suggested to interact with body fat to dysregulate appetite and be a source of overconsumption (42, 43). Hormonal responses to changes in energy intake and structured exercise have been observed; however, few studies have investigated their responses to increased time spent in sedentary activities. In a clinical trial of non-obese adults, only one day of inactivity, long hours of sitting, and minimal walking or standing, decreased insulin sensitivity even when energy intake was reduced to maintain energy balance (44). Subjects participated in three study sessions, mostly sitting without matching energy intake (SIT), sitting with matching energy intake (SITBAL), and no sitting (NO-SIT) (45). Three meals, breakfast, lunch, and dinner were exactly the same between SIT and NO-SIT. However, the caloric content of the breakfast and lunch were reduced by about 1,000 calories to match the reduction in energy expenditure in SIT-BAL. The next morning insulin action was tested. The results indicate that whole body insulin action was lower in SIT and SIT-BAL compared to NO-SIT (39 and 18% respectively). Therefore, both muscle inactivity and energy surplus contribute to the effect of prolonged sitting on insulin action. Further analyses examining gastrointestinal hormone response showed that SIT-BAL led to an increase in ghrelin in the men, but attenuated the leptin response, reduced ghrelin, increased hunger, and decreased fullness in the women. Because a reduction in energy expenditure was not accompanied by lower appetite, prolonged sitting may promote excess energy intake, leading to weight gain in both men and women. Physical inactivity has also been shown to interact with dietary macronutrient composition to influence energy and fat balance (46). Energy intake was not found to be regulated over a 2-day period in response to either imposition of inactivity or a high-fat diet (46). It was suggested that physical activity was essential to the avoidance of a significant positive energy balance.

From a practical standpoint, sedentary behavior is frequently associated with activities performed in a seated position. As previously discussed, there are potentially unfavorable stimulations that may be promoted by seated activities. However, these observations also reveal that the main problem of sedentariness in this context is maybe not the seated position, but rather the stressful stimulation that would accompany seated activities. For instance, in the context of usual daily activities seated labor can become stressful because of demanding cognitive effort, an inadequate sitting position, a stressful labor environment, or seated work that may be too long. Up until now, the biological mechanisms underlying stressful sitting activities have not been sufficiently documented; however, as discussed, our research experience suggests that stressful sitting may promote glycemic instability, hypercortisolemia and a reduced parasympathetic activity (18), which are all biological adaptations that are contrary to optimal metabolic fitness and body composition. Furthermore, up until now, there is no clear evidence that reading an interesting book in a seated position to relax before going to bed has negative effects (**Figure 1**).

SEDENTARY BEHAVIOR AND THE INADEQUATE SLEEPER

There is a resemblance between the biological effects of inadequate sleep compared to stressful seated work. In individuals with inadequate sleep habits, for example, glycemic instability has also been documented (47) and it is also well-known that short sleepers (<6 h/night) are more prone to excessive energy intake and thus, weight gain compared to individuals sleep 7–8 h/night (48). These observations add to the proof of concept, where it is not so much the nature of the sedentary activity, but the stress-related biological reality that may be related to it.

POTENTIAL SOLUTIONS TO COUNTERACT THE APPARENT DETRIMENTAL EFFECTS OF SEDENTARINESS

Clinical and public health guidelines for physical activity have been in place for nearly two decades (49); however, no quantitative guidelines exist for sedentary behavior because it is not known how much sedentary behavior is harmful to health. The impact of cognitive work as a sedentary behavior appears to be a stimulus favoring a significant enhancing effect on food intake and very trivial effects on energy expenditure. There is a clear disturbance in the context of modernity because of what we are accustomed to due to evolution. We have been configured to

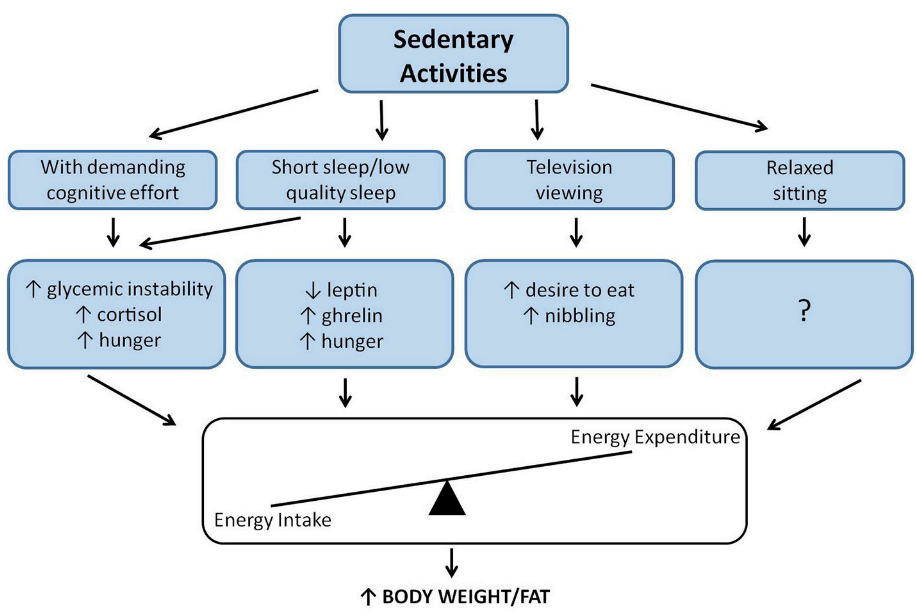

FIGURE 1 | Sedentary behavior and effects on appetite and glycemic control.

be hunter-gatherers and now we have chosen a modality of labor that is not optimally adapted to what we are used to. It would be difficult to return to the way of living of our grandparents using the "technology" of the past; however potential solutions that consider approaches to counteracting the negative impact of mental work may be possible with the readjustment of daily physical activity schedules.

In the context of a school or work environment, recent data has suggested that combining mental and physical work (e.g., active pauses/meetings), may be one strategy to reduce sedentary time in a context where potential neurogenic stress may be high. Both mental work and physical activity can influence hunger and food intake by producing various physiological changes. For example, an active exercise pause between a session of mental work and a buffet meal on energy intake and energy balance was found to represent a strategy to create a negative energy balance via an increase in energy expenditure and maintenance of energy intake (50). Furthermore, an acute bout of interval exercise after mental work was shown to decrease food consumption compared with a non-exercise condition suggesting that it may be used as an approach to offset positive energy balance induced by mental tasks (51). The school environment represents a good place for children and adolescents to improve the balance between physical activity and the cognitive demands of mental work. Students registered in a traditional sports studies program in ice hockey (school-related sessions in the morning and hockey-related activities in the afternoon) were found to experience a decrease in their body mass indices and increase in their aerobic and muscular fitness over the academic year without compromising their academic success (52). A physical education class prior to mental work was found to reduce blood pressure suggesting that physical education should be more prominent in schools and part of children's daily activities (53). Furthermore, elementary school children were found to be more physically active in an activity-permissive school environment up to the conditions of summer vacation conditions compared with a traditional school with chairs and desks and traditional school with desks which encouraged standing (54). The possibility of moving and even standing are good examples of modalities of cognitive work in which there is an inclusion of movement. The same scenario could be considered in a professional environment where active meetings could be developed to permit individuals to talk while walking or cycling on relevant machines.

Several years ago, our research group began active research meetings and examined its impact on perceived stress in staff and students at Laval University in Quebec City. A beneficial effect on self-reported stress and performance was found among staff and student members of the group suggesting that this may be one way to increase physical activity participation and improve the unfavorable effects of sedentariness on overall health. Computer-related activities which are common in both the school and work environment, for example, represent particular types of sedentary activities that are stressful and biologically demanding and thus, "re-designing" these environments may be essential to promoting more movement (54, 55).

Because sitting is widespread among desk-based activities, ergonomic adaptations including sitting-standing desks while working may be an approach that may decrease the negative effects of sedentary activities. Although the effects of sitting and standing on metabolism (e.g., blood pressure, glucose, and lipid metabolism) and cardiovascular risk is almost the same, evidence suggests that breaking up sedentary time with standing may be sufficient to improve productivity, relieve lower back pain and increase movement (56). In the workplace, sit-stand desks were found to be effective in decreasing workplace sedentary behavior in office workers with abdominal obesity, with no change in sedentary behavior or physical activity outside of work hours; however, these changes did not alter markers of cardiometabolic risk in these individuals (57). Furthermore, the use of sit-stand desks in sedentary office workers was also associated an overall sense of well-being and energy, decreased fatigue, and reduction in appetite, food intake and lower self-perceived levels of hunger (58). Introducing sit-stand desks was also shown to increase classroom standing time among university students who reported improvements in engagement, participation, attention and declines in restlessness, fatigue, boredom and cell phone use (59).

CONCLUSION

Based on the available evidence, sedentary behavior may be more than just physical inactivity. Calorie for calorie we deal with a profile of stimulation that may not necessarily have the same effects on appetite control, related peripheral biomarkers, and neuro-messengers. There appears to be a modern version of sedentary behavior that bears a potential neurogenic component leading to hyperphagia, stress, and unfavorable metabolic health outcomes; however, various approaches may help to increase physical activity participation that may possibly counteract the apparent unfavorable effects of sedentary behaviors. In the context of an environment where we are submitted to desk-based and computer-related activities, we must preserve our movement for optimal health and implement some of these strategies to increase physical activity participation in our schools and workplaces. Thus, socio-ecological interventions that consider multiple components are needed to help reduce sedentary behaviors and promote physical activity.

AUTHOR CONTRIBUTIONS

AT was responsible for the content of the manuscript. SP and AT wrote, read and approved the final manuscript.

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Organizational Culture and Implications for Workplace Interventions to Reduce Sitting Time Among Office-Based Workers: A Systematic Review

Wendell C. Taylor[1*], *Richard R. Suminski*[2], *Bhibha M. Das*[3], *Raheem J. Paxton*[4] and *Derek W. Craig*[1]

[1] Department of Health Promotion and Behavioral Sciences, Center for Health Promotion and Prevention Research, School of Public Health, The University of Texas Health Science Center at Houston, Houston, TX, United States, [2] Department of Behavioral Health and Nutrition, Center for Innovative Health Research, University of Delaware, Newark, DE, United States, [3] Department of Kinesiology, East Carolina University, Greenville, NC, United States, [4] Department of Community Medicine and Population Health, University of Alabama, Tuscaloosa, AL, United States

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***Correspondence:**
Wendell C. Taylor
wendell.c.taylor@uth.tmc.edu

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Background: Time spent in sedentary behaviors is an independent risk factor for several chronic diseases (e.g., cardiometabolic diseases, obesity, type 2 diabetes, and hypertension). Recently, interventions to reduce sitting time at work (a prominent sedentary behavior) have been developed and tested. Organizational culture plays a critical role in the success of workplace interventions. However, there are a limited number of studies that have examined the role of organizational culture in reducing sitting time in the workplace.

Objectives: Therefore, in this systematic review, we summarized the empirical literature investigating organizational culture and sedentary behavior in the workplace and identify gaps in the knowledge base.

Methods: We described the procedures of our systematic review and included two study flow diagrams that detailed the step by step process. Combinations of several search terms were used; the databases searched were PubMed, Medline, Academic Search Complete, and Google Scholar. We started with thousands of citations. After applying the inclusion and exclusion criteria, eight relevant articles were identified.

Results: For each identified article, the data extracted included citation, sample, objective, intervention, assessment of organizational culture and workplace sitting, findings, and implications. Each article was rated for risk of bias by population, intervention, comparator, outcomes, and study design (PICOS) analysis. The classification for each study was either: high-, moderate-, or low-quality evidence. Given the paucity of data, no definitive conclusions were presented; however, positive trends were highlighted.

Conclusions: Work place interventions to reduce sitting time at work may benefit from considering elements of organizational culture; however, the evidence to date is sparse and more high-quality studies in this area are needed. To advance the field of workplace health promotion, organizational culture, and interventions to reduce sitting at work, we present 11 recommendations.

Keywords: organizational culture, sit less, workplace intervention, sitting time, sedentary behavior, prolonged sitting, workplace culture, culture of health

KEY CONCEPTS

Organizational culture: Organizational culture is the shared values, beliefs, or perceptions held by employees within an organization or organizational unit (1).

Sedentary behavior: Any waking behavior characterized by energy expenditure ≤1.5 metabolic equivalents, while in a sitting, reclining, or lying posture (2).

Culture of health (COH): Environments with a culture of health, place value on, and are conducive to, employee health and well-being (3). A concern for employee health must permeate all aspects of an organization and its corporate identity (4).

INTRODUCTION

On average, Americans spend ∼9 h sleeping or engaging in personal care activities (5). In addition, Americans spend ∼8 h working or doing work-related activities; therefore, one-half of waking hours are related to work (5). So, what happens at work has undeniable consequences for physical, psychological, emotional, and social well-being. Unfortunately, in the workplace, sitting remains the dominant posture for office-based workers. Although there are detrimental health consequences associated with prolonged sitting, limited data exist on the variety of factors that contribute to this cultural norm.

Rationale

High levels of sitting are associated with increased risk of several adverse health outcomes including diabetes, heart disease, type-2 diabetes, and obesity. Sedentary behavior may be an independent risk factor for chronic diseases especially among adults with insufficient or low physical activity levels (6–8).

To reduce sedentary behavior in the workplace, understanding the influence of organizational culture on these behaviors is critical. Even though there are different definitions of organizational culture, an accepted definition is artifacts, espoused beliefs and values, and underlying assumptions (9). Artifacts are behaviors, rituals, language, myths, and dress. Espoused beliefs and values are typically reported by management as core to the organization. Underlying assumptions relate to organizational life and illuminates why organizational members go about their day-to-day work lives as they do (9). In essence, organizational culture is enduring, stable, and can take a long time to develop. In simple terms, organizational culture represents shared basic assumptions, values, and beliefs that characterize a setting and are taught to newcomers as the proper way to think and feel as employees of the organization.

Objectives

The importance of organizational culture and health outcomes has been documented. There is evidence that health promotion programs that incorporate more cultural elements in their strategies result in a reduction of employee health risks by as much as 5% per year, a level 2.5 times greater than health promotion programs without a cultural component (10). Another study found that most organizations with cultural support (66%) reported greater improvements in health behaviors compared to organizations with little or no cultural support (26%) (11). From a related perspective, organizations with very supportive leadership were almost 4 times more likely to report substantial improvements in employee health risks and 2.5 times more likely to report substantial improvements in medical cost trends. Importantly, the inverse was true. Organizations with minimally supportive leadership were ∼4 times more likely to report minimal improvements in both employee health risks and medical cost trends (12). Based on existing literature, we hypothesize that organizational culture can hinder or enhance intervention programs to reduce sedentary behavior in the workplace.

Research Questions/Specific Aims

Therefore, to reduce sedentary behavior, the implications and effects of organizational culture on sedentary behavior interventions merit systematic and thorough investigation. We found no reviews that specifically addressed this important topic. To fill this critical gap in our knowledge base, the objectives of this paper were to: (1) identify and describe the current literature related to organizational culture and sitting behavior at work; (2) identify gaps in the knowledge base; and (3) provide recommendations to advance the field related to reducing sedentary behavior among office-based workers.

MATERIALS AND METHODS

Study Design

All study designs were included and evaluated. The designs included randomized controlled trials (RCTs), cross-over RCTs, cluster-randomized controlled trials (cluster-RCTs), quasi-RCTs of interventions, non-randomized controlled trials, focus groups, and structured interviews.

Participants, Interventions, Comparators

The participants were any employees at the workplace. The interventions were designed to reduce sitting at work. The comparators were employees at the workplace who did not participate in the intervention.

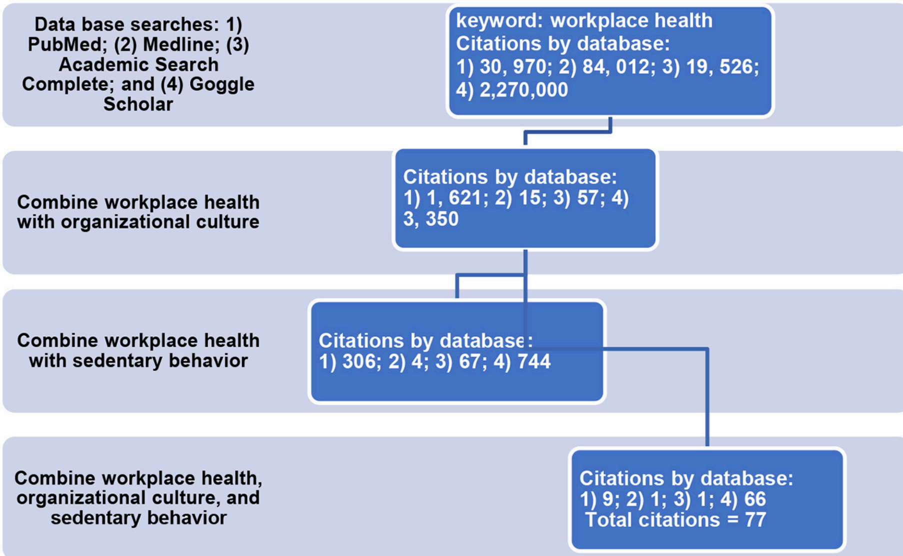

FIGURE 1 | Study flow diagram one: sequence of database searches. Keywords: workplace health, organizational culture, and sedentary behavior. Inclusion criteria for systematic review: primary data collection from employees or employers; data related to organizational culture and sedentary behavior. For Medline, we used the search term workplace health promotion instead of workplace health to meet the accepted terms for the database.

Systematic Review Protocol

The systematic review protocol involved independent reviews of identified articles by study investigators. Then consensus was achieved as to conformity with the inclusion and exclusion criteria. There were no disagreements that required a third party to adjudicate.

Search Strategy

The two study flow diagrams represent the major search strategy with four databases (PubMed, Medline, Academic Search Complete, and Google Scholar) and three key search terms—workplace health, organizational culture, and sedentary behavior. The inclusion criteria were primary data collection for organizational culture and sedentary behavior in the workplace. The exclusion criteria were non-English language study; theses or dissertations (not published in peer-reviewed journals); unable to obtain publication; and no primary data related to organizational culture and sedentary behavior in the workplace. Time frame was not limited given the novelty of research in this area. In addition to the main search strategy presented in Study Flow Diagrams One and Two (**Figures 1**, **2**), we conducted additional searches using combinations of key search terms from the following Medical Subject Headings (MeSH) terms: workplace culture, workplace, worksite, sitting, occupational sitting, and sedentary behavior. Furthermore, we reviewed the references of relevant articles such as review papers. We found no other appropriate references to add to the articles retrieved from the main search strategy.

Data Sources and Data Extraction

The data sources were: PubMed, Medline, Academic Search Complete, and Google Scholar. For each article, the data extracted included citation, sample, objective, intervention, assessments of organizational culture and sitting time, findings, and implications (**Table 1**). Each article was rated for risk of bias by population, intervention, comparator, outcomes, and study design (PICOS) analysis. The classification of each article was either: high-, moderate-, or low-quality evidence.

Data Analysis

From the main search strategy, two study flow diagrams show that we began with thousands of citations, applied all three keywords, and identified 77 potentially relevant articles. The inclusion and exclusion criteria were applied to the 77 articles and 8 relevant publications were identified to include in the data analysis. We reviewed eight articles and the data extracted were: citation, sample, objective, intervention, assessments of organizational culture and sitting time, findings, and implications (**Table 1**). Then, each article was rated based on high-, moderate-, or low-quality evidence and described in the text of the results section.

RESULTS

Provide a Flow Diagram of the Studies Retrieved for the Review

Study flow charts one and two represent the main search strategy from beginning to end. We started with thousands of citations and applied the inclusion and exclusion criteria which resulted in 77 articles; the final set included 8 articles.

Study Selection and Characteristics

The eight articles were summarized and evaluated based on population, intervention, comparator, outcomes, and study design (PICOS). High-quality evidence is characterized by studies with large sample sizes that are racially and ethnically diverse. An appropriate comparison group is identified. The study designs are RCTs, cross-over RCTs, cluster-randomized

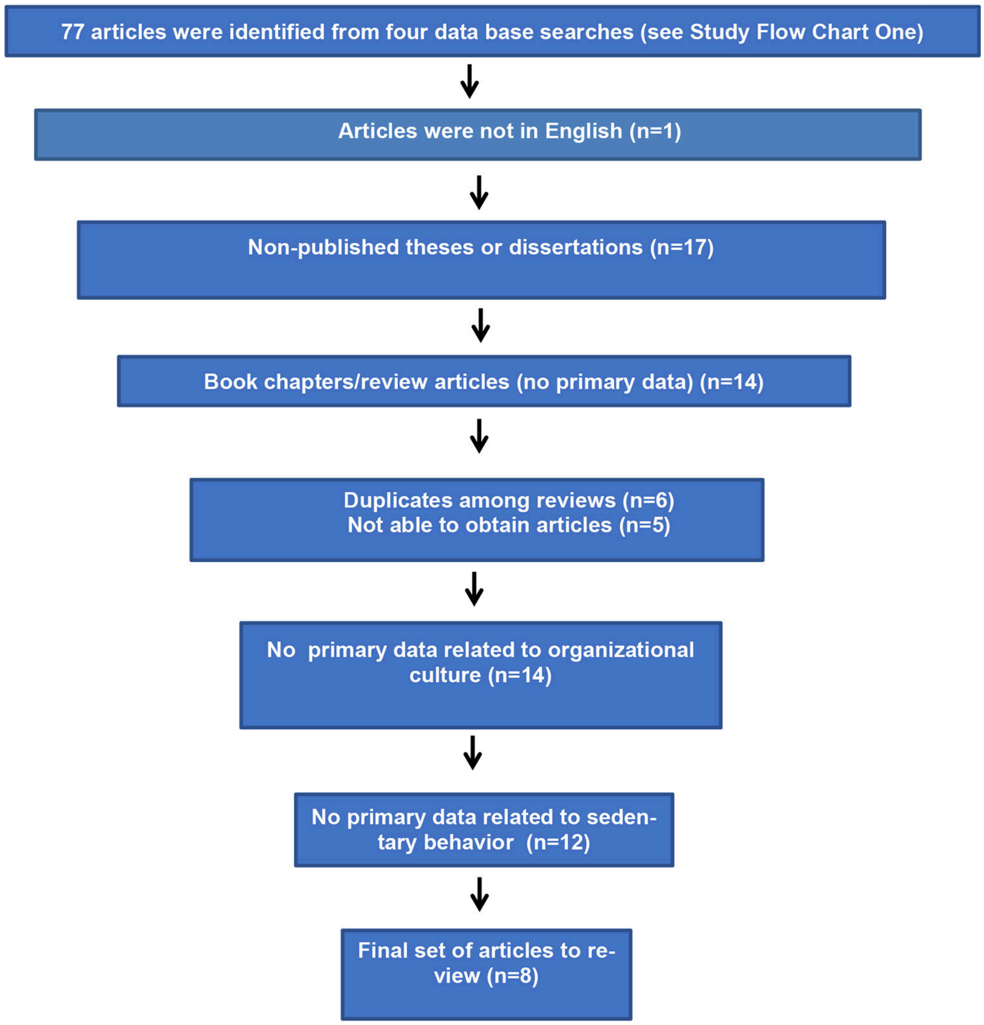

FIGURE 2 | Study flow diagram two: apply inclusion and exclusion criteria to 77 articles identified from four data searches (see Flow Chart One). Inclusion criteria for systematic review: primary data from employees or employers and primary data related to organizational culture and sedentary behavior. Exclusion criteria for systematic review: non-English language, thesis or dissertation (not published in peer-reviewed journal); unable to obtain publication; no primary data related to organizational culture and sedentary behavior.

controlled trials (cluster-RCTs), and quasi-RCTs of interventions. The studies with high-quality evidence have low risk of bias. Low-quality evidence is characterized by studies with small sample sizes, no comparison group, demographically homogeneous participants, no or flawed intervention, and weak study design (e.g., pre- and post-single sample). The studies with low-quality evidence have high risk of bias. One purpose of focus groups is to generate hypotheses for future studies. Nonetheless, from the perspective of the PICOS framework, focus group studies are low-quality evidence. Moderate-quality evidence is characterized by studies that do not meet the criteria for high quality evidence but are promising and superior to studies with low quality (e.g., non-randomized controlled trials). The studies with moderate-quality evidence have medium risk of bias.

High Quality Evidence

In a cluster-randomized controlled trial with 153 desk-based workers, organizational-support strategies designed to reduce sitting in office workers with and without an activity tracker were evaluated (14). The authors assessed the short-term (3 months) and long-term (12 months) effectiveness of the intervention. The organizational-support strategies consisted of a wellness champion choosing from a menu of choices and selecting options appropriate for each organization. The options included: an information booklet about sitting and health implications; five nightly emails with activity-promoting tips and images of active participants; participation of senior executives was communicated to employees; the workplace champion presented at least 10 workplace presentations, and informal discussions with managers continued throughout the study. The average time

TABLE 1 | Organizational culture and sitting at the workplace: literature review.

References	Sample	Objective	Intervention	Assessment of organizational culture	Assessment of sitting	Findings	Implications
Adeleke, et al. (13)	• Regional office of a large public sector service delivery organization in Australia. • 79 desk-based employees (26% of 300 possible) • Participants were mostly female (83%) and between 30 and 59 years of age (86%). Most had completed high school (83%), worked full time (60%), and had been employed at the organization for at least 3 y (68%). • Problem: High employees work place sitting time	Evaluate the effect of installing sit–stand workstations on their employees' workplace sitting time.	• Installation of electronic and fully adjustable sit–stand desks received information on how to use and adjust the workstation. • The intervention was conducted at a workplace that had previously implemented an intervention to reduce sedentary time at work. • The previous intervention involved educational materials aimed at encouraging workers to stand more at work.	Self-report survey on commitment of the workplace to their health and choice to stand and move at work	Self-report of work place sitting time using the Occupational Sitting and Physical Activity Questionnaire	No comparison group or alternative to the intervention 3-months post-baseline: - Sitting time decreased from 17% of work hours spent sitting to 13% (-80 min/8 h workday). - Standing time at work increased from 12% – 19% (+72 min/8 h workday). No significant effect on sitting time during nonworking hours	Participants agreed or strongly agreed that the workplace was: • Supportive of their health (84%) • Supportive of staff choice for standing and moving at work (74%). • The intervention was conceived and implemented entirely by workplace staff.
Brakenridge et al. (14)	Desk-based office workers from one organization randomized to: 1) Organizational support only (n = 46/87 completed intervention) 2) Organizational support + activity tracker (n = 25/66 completed intervention)	Evaluate the impact of organizational support strategies alone or with activity monitoring on sitting time at work.	Stand Up Lendlease, 12-month intervention to reduce sitting time at work.	• Survey used to assess the following work-related outcomes: • Job performance • Job control • Work satisfaction	ActivPAL3 monitors used to ascertain sitting time during work- and overall hours, prolonged sitting time (≥30 min bouts), time between sitting bouts, standing time, stepping time, and number of steps.	• Baseline (mean ± SD) 74.3 ± 9.7% of workday sitting, 17.5 ± 8. % standing and 8.1 ± 2.7% stepping. • No significant change in 3-month outcomes. • Significant (p < 0.05) reductions in both groups at 12 months in sitting time at work (−37 min/10 h), prolonged sitting at work (−43 min/10 h) and standing at work (+33 min/10 h) • After adjusted for confounders, the only significant between-group differences were a greater stepping time and step count for Group ORG + Tracker relative to Group ORG (+20.6 min/16 h day; +846.5steps/16 h day) at 12 months.	• Intervention using organizational support strategies to reduce sitting time at work are effective when they are worksite-driven and internally delivered. Minimally intensive nature of intervention is a positive.

(Continued)

TABLE 1 | Continued

References	Sample	Objective	Intervention	Assessment of organizational culture	Assessment of sitting	Findings	Implications
DeJoy et al. (15)	The present analyses were based on 1859 employees of Dow Chemical Company.	To evaluate the comparative effectiveness of environmental weight loss intervention alone vs. in combination with an individual intervention	The moderate intensity condition utilized a set of inexpensive and widely applicable environmental modifications aimed primarily at creating a more supportive work environment for physical activity and healthy eating. The high-intensity condition included all of the moderate interventions and several additional elements designed to engender a relatively high level of management engagement and support for the weight management goals of the project.	Environmental Assessment Tool was used to check the effectiveness of the environmental manipulation (moderate vs. intense to influence organizational culture).	Assessment of physical activity/inactivity based on a standardized Health Risk Assessment instrument. [Conceptual and measurement distinctions between physical inactivity (outcome in article) and sedentary behavior (inclusion criterion for this review) have been reported (16). Nonetheless, we chose to include this article because of its emphasis on changing organizational culture with moderate and intense environmental interventions].	Employees who participated in the individual program were no more successful at losing weight than those exposed to only the environmental interventions. Those participants in the individual program at the environmental intense sites were 1.87 times more likely than non-participants to reduce their risk of physical inactivity (*P* = 0.0082).	• Based on process data, the authors concluded that management support must be effectively communicated at levels of the organization most notably to rank-and-file employees.
Hadgraft et al. (17)	Convenience sample of 10 men and 10 women. Employees and managers in retail, health and IT industries with no formalized programs to reduce sitting.	Explore barriers to reducing office workplace sitting, and the feasibility and acceptability of strategies targeting prolonged sitting in the workplace	None	Semi-structured interviews covering barriers to reducing sitting, the feasibility of potential strategies aimed at reducing sitting, and perceived effects on productivity	• The Occupational Sitting and Physical Activity Questionnaire • Outcome: Percentage of time at work spent standing, sitting, and moving during a typical work day in the past week.	• Median 7.2 h/d spent sitting at work • Sitting time at work related to: • Reliance on computers for work • Workload • Having furniture designed for a seated posture • Standing, stretching and/or moving about the office related to: • Concerns about appearance (e.g., looking "weird") • Needs to reduce sitting time at works were: • Low cost strategies (e.g., standing meetings) • In-person communication about reducing sitting time	• Low-cost strategies (e.g., standing) may be feasible and acceptable approaches to reducing sitting time at work. • Barriers to uptake that should be considered are social norms and workload • Two key elements that seem essential for work-related sedentary behavior change to occur are: -Raising worker awareness about the health risks of sitting at work

(Continued)

TABLE 1 | Continued

References	Sample	Objective	Intervention	Assessment of organizational culture	Assessment of sitting	Findings	Implications
						• Evidence supporting a business case to reduce sitting at work (noted by managers).	• -Building supportive organizational cultures • The business case for reducing sitting at work needs to be strengthened through research on productivity and cost-effectiveness
Hadgraft et al. (18)	• Office-based workers at 14 government worksites • 121 intervention and 87 controls completed 3-month follow-up • 97 intervention and 70 controls completed 12-month follow-up • Mean age 45.6 ± 9.4 y 68.4% female, 79.4% Caucasian, 66.8% had post-school education, and 79.2% worked full-time	• Assess the impact of the intervention on four social-cognitive constructs • Examine if the four constructs mediated intervention effects on workplace sitting	• Stand Up Victoria • Organizational, environmental and individual level approach to reduce workplace sitting time.	Self-administered online questionnaire measuring: Perceived organizational norms Perceived organizational/social support for sitting less at work.	ActivPAL3 activity monitor used to measure workplace sitting time	• No significant effect on perceived organizational norms at 12 months • No relationship between changes in perceived organizational norms and changes in workplace sitting time at 3 and12 months • Self-efficacy for overcoming barriers to sitting less at work mediated intervention effects on workplace sitting time (indirect effect: −10.3 min/8 h day; 13.9% of total effect)	• Interpersonal and environmental levels of influence on initiating and maintaining workplace sedentary behavior change need to be better understood to improve intervention development and refinement.
Healy et al. (19)	43 participants	Changes in minutes/day at the workplace spent sitting (primary outcome)	4 week intervention with organizational, environmental, and individual components	Assessed organizational support for successful intervention adoption with consultation with company representatives and management.	ActivPAL3	• Compared to controls, intervention group significantly reduced workplace sitting	• Organizational change evidenced through workplace social norms and workplace culture is likely to take longer than a 4-week study to become institutionalized.
Flint et al.(20)	Convenience sample of 21 office workers from small to medium-sized UK companies	Explore employees' perceptions of sitting time	None	Four focus groups comprised of non-managerial employees and one focus group of managers. Asked about: Perceived association	Workforce Sitting Questionnaire International Physical Activity Questionnaire (IPAQ) short form	• Mean sitting time was 6.4 h/d • Employees indicated they: • Sat too long at work • Know about the link between prolonged sitting at work and increased risk of chronic health problems • Barriers to Sitting Less and Moving More • Sitting was integral to their occupational role	• Organizational culture should be considered in the design and implementation of workplace interventions to reduce sitting time.

(Continued)

TABLE 1 | Continued

References	Sample	Objective	Intervention	Assessment of organizational culture	Assessment of sitting	Findings	Implications
				between sitting time and health. Strategies that could be used to break up or reduce prolonged sitting at work.		• Organizational culture • Lack of motivation • Physical environment (e.g., lack of sit-stand desks) • Poor quality recreational facilities on-site and no managerial support for using it • Strategies to Reduce Sitting at work • Organizational support and encouragement to reduce sitting time at work • Have employer provide evidence-based information on the risks of sedentary behavior • Incentives • Allowance to take breaks at work	• Personal determinants and the workplace environment also play key roles in reducing employees' sitting behavior at work.
Such and Mutrie (21)	• Seven men and six women who had participated in the Sit Less and Walk More intervention. • All were engaged in predominantly desk-based work.	Examine the organizational cultural factors that impede and promote reduced sitting time in the workplace.	• "Sit Less" health promotion intervention with the following components: • Sit Less and Walk More' 4-week, pedometer intervention • Awareness-raising sessions highlighting issue of sitting time at work. • Posters encouraging physical activity placed at key decision-making points around the workplace	• Face-to-face in-depth interviews • Analyses of four workplace policy documents • Employee workplace handbook • Employee mental health and wellbeing statement • Health and safety components of the organization's annual reports • Organization's strategic plan and performance framework.	• A 'sit less and walk more' 4 week intervention. Thirty-five volunteers took part • In this phase: They were provided with pedometers to record steps taken at work. • Baseline measures were taken in week one. This was followed by a one-to-one counseling intervention which aimed to help participants identify where, how and when sitting time could be reduced and step counts increased. Steps were then recorded for a further 3 week period.	• More sitting at work related to: • Greater work demands • Policy, rules and regulations such as working from home and home flexi-time (both *encouraged* more sitting) • Working in silos limited chance to move around work space • Issues such as family life, transport, and the nature of the modern working environment • Lack of formal practices and mention of sitting time in organization's documents.	• To effectively reduce sitting time at work it is important to consider a range of structural, organizational and cultural factors and their dynamic interactions

spent sitting during work and overall were the primary outcomes. A secondary outcome was the number of steps per day.

With or without an activity tracker, organizational-support strategies showed improvements in sitting and standing. At 3 months, both interventions resulted in small and non-significant differences in sitting time and activity outcomes. At 12 months, both interventions resulted in statistically significant reductions in sitting time. The activity tracker condition showed increases in overall stepping time and step counts. Improvements were most evident at 12 months. The authors concluded that embedding changes in an organization is not a rapid process and it takes time to generate organizational culture change. Furthermore, behavioral improvements can occur without environmental modifications. This study was the first to report the impact of organizational support and activity tracker strategies on office workers' sitting time (14).

In another study, building on a multi-component trial that successfully reduced sitting in the workplace, the purpose was to provide insights into the mechanisms (mediators) to explain the results (i.e., reduced sitting) by examining short- and long-term mediation effects (18). Two hundred and thirty-one office-based workers were randomly assigned to intervention and control conditions by worksite. Workplace sitting was measured with the activPAL3 device. Participants reported spending 7.2 h (median) of their working hours sitting. The intervention was composed of organizational, environmental, and individual level components. The organizational level intervention was tailored management emails. To evaluate perceived organizational norms, levels of agreement were assessed to the statement; "My workplace is committed to supporting staff choices to stand or move more at work." Based on mediation analysis, social norms around appropriate workplace behavior and workload pressures were perceived as barriers. Furthermore, the intervention significantly improved perceived organizational norms at 3 months but not at 6 months. The authors noted that the organizational level intervention designed to improve workplace culture was discontinued at 3 months. It was recommended that future workplace interventions invest in longer organizational cultural change strategies to sustain perceived cultural changes related to moving more and sitting less (18).

A quasi-experimental research design, with 1,859 employees, was used to compare the outcomes for two levels of environmental interventions and for participants who did or did not simultaneously self-select into an individually focused weight loss intervention (15). In essence, the comparative effectiveness of environmental weight loss interventions alone vs. in combination with an individual intervention was evaluated. The outcomes of interest were weight loss and physical activity/inactivity. The goal for the moderate environmental interventions was to utilize a set of simple, low cost interventions that would be easy to implement in a wide variety of workplaces and that could be sustainable over time. The intense environmental condition was designed to engage leadership and create a more positive and supportive climate for health. The individually focused program consisted of setting a weight-related goal and reporting baseline weight at sign up and providing self-reported weight information three times after signup at 3-month intervals. The results were that employees who participated in the individual intervention were no more successful at losing weight than those exposed to only the environmental interventions. However, those who participated in the individual program at the intense environmental intervention sites were 1.87 times more likely than non-participants to reduce their risk of physical inactivity ($P = 0.0082$).

The moderate and intense environmental conditions differed significantly across time in terms of supports for nutrition and weight management and general organizational supports; the environmental manipulation was effective with some fading during year 2 of the intervention. However, the authors noted that leadership engagement failed to impact frontline employees at a subjective or perceptual level. The recommendation from this study was that management support must be effectively communicated so that visible actions and tangible changes that impact the daily work life of rank-and-file employees can be observed. Environmental interventions may be most effective when they are publicized through multiple channels and accompanied by policy actions that reinforce the desired behaviors. [An explanatory note about the inclusion of this article in our review; conceptual and measurement distinctions between physical inactivity (outcome in article) and sedentary behavior (inclusion criterion for this review) have been reported (16). Nonetheless, we included this article because of its emphasis on changing organizational culture with moderate and intense environmental interventions].

Moderate-Quality Evidence

During a 4-week, two arm, non-randomized controlled trial, an intervention with organizational, environmental, and individual elements was implemented (19). The primary outcome of interest was workplace sitting time. There were 43 participants. The organizational support included emails providing "standing tip of the week" and a workshop focusing on the health consequences of excessive sitting. Organizational support strategies were adjusted based on consultation with organization's representatives and management. Environmental strategies were the installation of dual display sit-stand workstations. The individual interventions were an initial 30-min face-to-face consultation between a health coach and each intervention participant followed by three telephone calls (one per week). The sessions emphasized behavior change strategies such as goal setting, self-monitoring, and problem solving. In comparison to the control group, the intervention group significantly reduced workplace sitting time; workplace sitting was almost exclusively replaced by standing. Because the intervention period was 4 weeks, the authors reported that most of the change was attributable to environmental and individual strategies; however, it was acknowledged that organizational support was essential. The authors concluded that organizational strategies to change workplace social norms and workplace culture will take longer that a 4-week intervention to become institutionalized (19).

Low Quality Evidence (i.e., Convenience Sample, Focus Group, and Interview Studies)

A study examined the impact of installing sit–stand workstations on their employees' sitting time at work (13). The intervention was conducted with a convenience sample of 79 desk-based employees working at a large, service delivery organization in Australia. Employee perceptions of organizational culture and sitting time at work were assessed before and after the employees were given sit-stand work stations. No comparison group was used. Results were positive and indicated that the intervention decreased sitting time at work by an average of 80 min/8 h workday and increased standing time by an average of 72 min/8 h workday. In addition, employees believed that the workplace was supportive of their health (i.e., organizational culture) and the employees had a choice of standing and moving at work. This study was deemed low-quality evidence because it had many limitations related to its study design (e.g., small percentage of staff participated) and no comparison group.

In another research project, the volunteers for a qualitative sub-study were part of a larger study that included pedometers to record steps and one-to-one counseling sessions to reduce sitting and increase step counts (21). Based on a model of organizational culture, qualitative, face-to-face, in-depth interviews were conducted with 13 volunteers. The model of organizational culture included the constructs of values and belief system, strategy, structure, and operations affected by the external environment. The findings from the qualitative study were that the "inevitability of time pressure" and the work ethic to "get things done" undermined the motivation to reduce sedentary behavior. It was recommended that the organization appoint a "champion for sitting less." Basically, the norm of sedentary time was unchallenged by the work hierarchy (21). The authors concluded that to change sitting as a norm, a whole systems approach is needed that includes workplace policy and norm-changing interventions. Co-produced interventions (employees, employers, management and scientists working in partnership) can challenge sedentary behavior at different and interconnected organizational levels.

In another qualitative study, with a convenience sample of 21 employees, self-reported occupational sitting time was 6.4 h (20). The purpose of the five focus groups was to explore perceptions of health risks associated with prolonged sitting and potential strategies to reduce sitting at work. Four focus groups consisted of non-managerial employees and one focus group was exclusively managers. The majority of participants had experienced negative symptoms associated with sitting at work including neck and back pain, poor posture, weight gain, and reduced concentration. In addition to personal determinants, employees highlighted the key role of workplace environment and organizational culture in reducing sitting behavior at the workplace. One of the barriers to reducing sitting time was the chargeable time culture; everything needs to contribute to the organization's productivity. One respondent cited "Sit at your desk for a lunch break and eat while working." To change culture, it was recommended to have corporate endorsement of well-being champions and communication at all levels within the organization (20).

In a different qualitative study (semi-structured interviews), with a convenience sample of 20 participants from three organizations, the objective was to assess perceptions about reducing workplace sitting (17). None of the workplaces had implemented any formal interventions to reduce prolonged sitting time. The purpose of the study was to identify barriers to reduce sitting and perceptions about a range of sitting reduction strategies. On average, participants reported sitting at work 7.2 h per day (minimum was 4.0 h and maximum was 9.5 h). The three prominent barriers to reduce workplace sitting were: the nature of work, organizational social norms, and office furniture and layout. Organizational social norms were perceptions of what was considered normal as workplace behavior. Related to organizational influences, the respondents were asked: "What level of priority do you think your organization places on reducing sitting time at work." The authors concluded that building a supportive organizational culture and raising awareness of the adverse health effects of prolonged sitting may be important to improve individual level and other strategies for change (17).

Synthesized Findings

In summary, the empirical database is limited; no definitive conclusions are presented. The majority of the studies were focus groups and qualitative interviews with data to generate hypotheses for interventions. Basically, more intervention studies are needed. Our preliminary assessments to be confirmed with additional studies are that workplace interventions to reduce sitting time: (a) can be low-cost (e.g., stand rather than sit at meetings); (b) should include efforts to raise awareness regarding the negative health effects of prolonged sitting at work; (c) need to target multiple levels (e.g., employees, employers, individual, social, environmental, and organizational); (d) need to have strong and clear components that focus on organizational culture and; (e) should make a business case (e.g., increased productivity) related to reduced sitting at work.

Risk of Bias

In a recent Cochrane review (22), risk of bias was assessed in the following domains: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective outcome data, validity of outcome measure, and baseline comparability/imbalance for age, gender, and occupation of groups. Each potential source of bias was graded as high, low, or unclear with justification for the judgments. These eight domains have marginal relevance and applicability to a database with eight studies. There were three high-quality evidence papers; one moderate-quality evidence paper; and four low-quality evidence papers. The low-quality evidence papers were primarily focus group studies or semi-structured interviews. Given the limited database and predominance of qualitative studies, the risk of bias is unclear.

DISCUSSION

Summary of Main Findings

As noted in the Introduction section, definitions of organizational culture are essential to workplace health promotion. A clear definition is needed for the field to move forward. A pioneer in the study of organizational culture, Schein (23) in his recent book, presents a dynamic definition of organizational culture.

> "The culture of a group can be defined as the accumulated shared learning of that group as it solves its problems of external adaptation and internal integration; which has worked well-enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think, feel, and behave in relation to those problems. This accumulated learning is a pattern or system of beliefs, values, and behavioral norms that come to be taken for granted as basic assumptions and eventually drop out of awareness" (page 6) (23).

What is noteworthy about this definition from the perspective of researchers and practitioners is that there are distinct levels of observability for learned patterns of beliefs, values, assumptions, and behavioral norms. Of the constructs noted above, behavioral norms are the most visible and represent an expression and manifestation of assumptions, values, and beliefs.

Given this definition, the primary conclusion from this review is that literature documenting the role of organizational culture on sedentary behaviors at work is sparse (i.e., only eight studies) and fairly recent (i.e., six of eight papers published since 2016). The outcomes, however, from the available studies suggest that efforts to reduce sitting time at work are promising when organizational culture is considered. Further research in this area is warranted. Therefore, we present 11 recommendations to guide and advance the field.

Recommendations

- Mechanisms, mediators, and processes that influence organizational culture include leadership, organization's mission statement, management and strategic communication, management behavior, employee autonomy/empowerment, coworker support, employee engagement, values, belief systems, environmental supports, policies, and practices (24). Similar to an earlier study (24), we recommend identifying what matters most for changing how employees think and feel about the organization's support for health and reducing sedentary behavior. The potential targets are policies, environmental supports, and clear and favorable upper- and mid-management communication.
- In a comprehensive review of the measurement of workplace culture, most instruments did not focus on workplace *health* culture (12). Instead, subscales related to the culture of health were identified. One exception is the Lifegain Wellness Culture Survey (also known as the Lifegain Health Culture Audit), which measures five core dimensions of culture—values, norms, touch points, peer support, and climate (11). The validity and reliability of this instrument have been measured in several studies (11). Instruments related to the overall culture of the organization include: The Organizational Culture Inventory, the Denison Organizational Culture Survey, and the Organizational Culture Profile (25). The challenge of measuring organizational culture has been noted by several authors (25). Most quantitative measures of culture capture the espoused values and/or behavioral norms in organizations and not the full richness of the construct—including myths and stories. A focus on intangibles related to organizational culture makes a complete reliance on quantitative approaches unsatisfactory, emphasis should be placed on qualitative assessments (25).
- Organizational culture should be studied in conjunction with organizational climate. Climate and culture can be mutually supportive. Climate is more sensitive to workgroup norms and highly variable across an organization, whereas culture is more enduring and stable across the entire organization (12). Organizational climate is defined as the mood or unique "personality" of a workplace (26). Organizational climate, also, has been defined as the shared perceptions of and the meaning attached to the policies, practices, and procedures employees experience and the behaviors they observe getting rewarded and that are supported and expected (25). On the other hand, as noted earlier, organizational culture is defined as the shared basic assumptions, values, and beliefs that characterize a setting and are taught to newcomers as the proper way to think and feel and are communicated by the myths and stories people tell about how the organization came to be the way it is (25). In this paper, we focused on organizational culture because it is more enduring and stable than organizational climate. For example, a charismatic leader affects the organizational climate. When a charismatic leader departs a company the organizational climate can change dramatically; however, the organizational culture remains basically intact. Nonetheless, the relationships between climate and culture can be mutually reinforcing and both merit empirical analysis.
- Organizational culture should be studied as potential antecedents, consequences, moderators, and mediators for interventions designed to reduce sedentary behavior. In previous research, organizational culture was studied as a contextual variable that moderated relationships between and among other constructs (25). For example, can dimensions of organizational culture weaken or strengthen the relationship between organizational justice and leader-member exchanges (25)?
- In understanding culture, the socialization experiences of newcomers can be critical because typically, newcomers see everything with fewer preconceptions and fresh perspectives. If a newcomer affiliates him/herself with individuals who embody the positive values of the organizations, s/he will embrace the culture quickly. In the context of sedentary behavior, regular displays of reducing sedentary behavior and an active workplace culture will facilitate positive behavioral changes. However, the reverse is also true. Zappos is a prime and clear example of hiring according to cultural standards and insuring that newcomers embrace the culture. This company, which specializes in shoes (online sales),

hires employees based on their potential to fit into the organizational culture (referred to as cultural fit interviews). Consistent with this mission, new hires are offered $2,000 to quit after 1 week if they perceive the job or company culture is not for them. The bottom line is that Zappos values its culture and does not want anyone who is unhappy or dissatisfied to disturb and disrupt the organizational culture. The objective is to have the entire corporation and brand supported by a loyal and dedicated workforce who provides great customer service (https://www.entrepreneur.com/article/249174).

- More research studying the effectiveness of integrating and combining individual approaches with cultural components to reduce sedentary behavior is needed. Thus, should organizations focus both on top-down and bottom-up approaches to create the needed paradigm shift to move behavior from one norm to another? Policy and environmental supports combined with individual level interventions need further research to understand what shifts organizational culture.
- Related to recommendation #6, what elements of an intervention are needed to embed the processes and mechanisms to change an organizational culture to a "culture of health?" Well-designed investigations are needed to determine what proportion of employee health improvement is due to cultural support (12). If shown to be reliable and valid, an assessment can be used by organizations to document improvements in the organization's culture of health. This information is valuable because it can document whether policy and environmental changes are sufficient to influence organizational culture in a meaningful way. In addition, such a tool could assist organizations in evaluating the impact of organizational culture on employee health and outcomes (12). More research in this area can be impactful.
- To what extent is workplace culture influenced by societal, cultural, or national norms? An international group of experts convened to provide guidance for employers to promote the avoidance of prolonged periods of sedentary work (27). The recommendations are: for those occupations which are predominantly desk-based, workers should aim to initially progress toward accumulating 2 h per day of standing and light activity (light walking) during working hours, eventually progressing to a total accumulation of 4 h per day (prorated to part-time hours). To achieve these recommendations, seated-based work should be regularly broken up with standing-based work, the use of sit–stand desks, or taking short active standing breaks (27). To what extent these recent guidelines are known and embraced by organizations including managers and employees has not been documented. Nonetheless, societal norms can influence a workplace's organizational culture.
- To what extent is a "culture of health" influenced by life cycles of organizations? Are newer or more established (mature) organizations more likely to have a "culture of health" or a "wellness culture?" To what extent is a "culture of health" influenced by the profitability and/or organizational effectiveness of the company? The culture of health may depend on the bottom line. If a company is struggling or still fighting for survival, then health may not be a priority. If an organization is thriving, perhaps it has greater flexibility and can embrace healthy practice policies and a culture of health. More research is needed in this area.
- The prevalence of workplaces with "cultures of health" is unknown. Large organizations with established health promotion programs may be more likely to have some level of cultural support for health. Perhaps, in mid-size and small companies, the presence of workplace wellness efforts may be less common and information regarding the existence of supportive cultures more difficult to assess. On the other hand, smaller companies may be able to create and retain a culture of health more easily than large companies that have many more employees and greater organizational complexity. The size of an organization and workplace "culture of health" merits further study (12).
- Related to reducing sedentary behavior is promoting physical activity during the workday. There have been several reviews and empirical studies related to promoting physical activity during the work day (28–38). For example, research has documented that mid-management support is critical in determining whether employees can consistently participate in 15-min, group physical activity breaks during the work day (39, 40). The lessons learned from physical activity promotion during the workday can inform research on reducing sedentary behavior during the workday and organizational culture change.

Limitations

In this systematic review, an inclusion criterion was peer-reviewed published articles. We did not search sources of gray literature and unpublished studies and data; unpublished theses and dissertations were excluded. A limitation of this review is publication bias. In addition, we excluded articles published in languages other than English. Our review may be subject to language biases. Furthermore, studies with interventions that incorporated individual, environmental, and organizational elements were excluded unless specific measures of organizational or workplace culture were assessed. Some consideration of organizational or workplace culture had to be acknowledged. We found no similar reviews to compare our findings.

CONCLUSIONS

Prolonged sitting, aggregated from work and in leisure time, may significantly and independently increase the risk of cardiometabolic diseases and premature mortality (6–8). To reduce sedentary behavior at work, organizational culture merits careful analysis. Allen presented a metaphor that workplace or organizational culture creates fertile ground in which healthy lifestyles (the good seeds), can take root and flourish (11). The organizational culture can be strong or weak. Nevertheless, organizational culture influences the meaning of workplace behaviors as well as the adoption, implementation, and effectiveness of health promotion initiatives. In a national meeting of thirty-five of the most experienced practitioners and researchers in workplace health promotion (i.e., professional think tank), four research priorities were identified. Of the four top ranked research priorities, healthy organizational culture was ranked number one as a research priority (41). The experts in health promotion and wellness concluded that a health-oriented or wellness workplace culture permits and enables healthy lifestyle choices and significantly enhances long-term program success. In other words, a strong cultural foundation sustains health-promotion initiatives in contrast to a primary reliance on targeted individual intervention strategies.

For example, prior to the development of the intervention, a formative research study was conducted to reduce workplace sitting time using height-adjustable workstations (not focused on organizational culture; thus, ineligible for our literature review) (42). A systematic assessment was implemented to inform the development of the intervention. The guiding theoretical frameworks were: Theoretical Domains Framework, Community Readiness Model, and the Behavior Change Wheel (incorporating capability, opportunity, and motivation). The assessment included eight steps. The findings were that motivation to change behavior was low because of the dominant work culture of sitting. The authors acknowledged that their comprehensive and participatory approach to identify barriers and facilitators to reduce sitting time and their focus on individual behavior change that excluded organizational policies and practices were a major limitation of their approach (42).

Substantial and enduring health promotion improvements depend upon individual initiatives and organizational culture working in partnership (i.e., mutually supportive) (11). To create a favorable organizational culture, senior leadership commitment, front-line managers' engagement, "boots-on-the-ground" personnel mobilizing grassroots efforts, strong supportive policies, health-promoting environments, and highlighting employee health as an important business objective are recommended as essential elements to "building a culture of health" in a sustained way at the workplace.

In summary, a purpose of this systematic review was to add clarity and depth to the existing literature. Even though the findings are promising from a limited database, basic questions remain: What is the evidence that strategies to reduce workplace sitting (e.g., workplace champion and management communication) influence organizational culture? What is the time frame to observe changes in organizational culture? What is the evidence that changes in organizational culture from interventions contribute to behavior change in the workplace? As more rigorous research is conducted and evaluated to address these challenges, we will move closer to achieving our goal of reducing sedentary behavior at the workplace and improving the health of all employees.

AUTHOR CONTRIBUTIONS

WT conceived of the study. RS, BD, RP, and DC contributed to the development and design of the study. WT and RS organized the literature review. WT and RS conducted the literature review and wrote the results section. WT wrote the first complete draft of the manuscript. RS, BD, RP, and DC revised sections of the manuscript. All authors contributed to manuscript revisions, read, and approved the submitted version.

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Effect of Work-Related Sedentary Time on Overall Health Profile in Active vs. Inactive Office Workers

Pauline M. Genin[1,2,3,4*], Pascal Dessenne[5], Julien Finaud[6], Bruno Pereira[7], Frederic Dutheil[1,2,8,9], David Thivel[1,2] and Martine Duclos[2,3,4,10]

[1] Clermont Auvergne University, EA 3533, Laboratory of the Metabolic Adaptations to Exercise under Physiological and Pathological Conditions (AME2P), Clermont-Ferrand, France, [2] CRNH-Auvergne, Clermont-Ferrand, France, [3] INRA, UMR 1019, Clermont-Ferrand, France, [4] University Clermont 1, UFR Medicine, Clermont-Ferrand, France, [5] Caisse Primaire d'Assurance Maladie, Clermont-Ferrand, France, [6] Association Sportive Montferrandaise, Clermont-Ferrand, France, [7] Clermont-Ferrand University Hospital, Biostatistics Unit (DRCI), Clermont-Ferrand, France, [8] School of Exercise Science, Australian Catholic University, Sydney, NSW, Australia, [9] Occupational Medicine, University Hospital CHU G. Montpied, Clermont-Ferrand, France, [10] Department of Sport Medicine and Functional Explorations, Clermont-Ferrand University Hospital, G. Montpied Hospital, Clermont-Ferrand, France

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Edited by:
Daniel P. Bailey,
University of Bedfordshire Bedford,
United Kingdom

Reviewed by:
Evangelia Nena,
Department of Medicine, Democritus
University of Thrace, Greece
Siti Munira Yasin,
Universiti Teknologi MARA, Malaysia

***Correspondence:**
Pauline M. Genin
pauline_genin@hotmail.com

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Objective: While public health strategies are developed to fight sedentary behaviors and promote physical activity, some professional activities, and especially tertiary ones, have been pointed out for their highly sedentary nature. Although workplace physical activity programs are increasingly proposed by companies to their employees in order to increase their physical activity levels, sitting and screen time remain extremely high. The main aim of this work was to compare health indicators between active and inactive tertiary employees with similar high levels of sedentariness. Secondly, we questioned the effects of a 5-month workplace physical activity program on overall health indicators among initially active and inactive tertiary employees.

Methods: Anthropometric measurements, body composition (bio-impedance), physical fitness (cardiorespiratory and musculoskeletal fitness) and health-related quality of life and perception of health status (self-reported questionnaires) were assessed among 193 active and inactive tertiary employees before (T0) and after a 5-month workplace physical activity intervention (T1), composed of 2 physical sessions per week.

Results: Significant improvements were found in performance of push-ups ($p < 0.001$), back muscle strength ($p < 0.001$) fat mass ($p < 0.01$) and waist circumference ($p < 0.05$) in active compared with inactive employees both at baseline and at the end of the program. Health perception ($p < 0.001$) was significantly different between groups at T0 but not at T1. However, no significant difference was observed for fat-free mass, BMI, workplace well-being and lower and upper limbs muscle strength. The variations between T0 and T1 demonstrate that, while all the studied parameters progressed positively during the 5-month program, health perception ($p < 0.001$), back muscle strength ($p < 0.05$) and BMI (tendency) showed a significantly higher progression in the inactive compared with the active group.

Conclusion: Health indicators might not be improved among active tertiary employees compared with inactive ones, which might be due to the high level of sedentariness characterizing their occupational task.Structured on-site physical activity programs can improve health in both initially active and inactive employees.

Keywords: tertiary employees, physical activity, sedentariness, health, fitness

INTRODUCTION

Over the last decades, sedentariness has become one of the largest public health concerns, recognized as one of the main causes of preventable premature mortality. Diaz et al.recently highlighted that both the total volume of sedentary time as well as its accrual in prolonged, uninterrupted bouts are associated with increased all-cause of mortality (1), which has been associated with poor health at all ages, independently of the level of physical activity (2). It is crucial to clarify that sedentariness is not the same as lack of physical activity, as people can reach the recommended levels of physical activity for their age, yet spend a large amount of their time engaging in sedentary activities (3, 4). Evidence suggests that the time dedicated to sedentary activities (leisure and work) has increased from 26 to 38 h per week between 1965 and 2009 in the United States and from 30 to 42 h between 1960 and 2005 in Great Britain, expressing alarming prospects for 2030 (5). According to the 2006 national nutrition and health survey (ENNS), 53% of adults aged 18 to 74 (59% of men and 48% of women) spend 3 h or more per day (working days and holidays) in front of a screen (television or computer) outside of working hours. Importantly, this proportion progresses with age in both men and women.

When it comes to work-related sedentary time particularly, it appears that the prevalence of sedentary professions increased by 20% in the United States between 1960 and 2008, with a concomitant decline of more "physically active professions" (5). In France, working adults have been shown to spend on average 9.96 h per day sitting on workdays (with at least 4.17 h/day seated at work) and 7.58 h/day sitting on non-workdays (6). Importantly, Saidj et al. reported clear associations between the sedentary time at work and the adoption of sedentary behaviors outside work.

Worldwide, public health policies underline the urgent need to create a suitable culture of regular physical activity (7), where employers are encouraged to play a key role in the promotion of health and well-being among adults of working age (8).

Workplaces represent today an ideal opportunity for new initiatives to promote physical activity. Workplaces could indeed reduce some of the barriers that have been identified to limit the engagement in physical activity, such as lack of time and proximity (9). Due to the difficulties in changing the habits of populations and to promote physical activity in usual settings (such as associations, gymnasiums, etc.), workplace-based programs might provide a great way to incite employees to increase their activity levels, especially due to the amount of time people spend at their workplace (10). There is clear evidence that increasing the employees' level of physical activity has beneficial effects on their health, concomitantly reducing health care costs (11) and the cost of different treatments for preventable diseases, and decreasing the number of sick leave due to diseases or injuries (12, 13). Some previous studies have indeed shown that interventions conducted to improve employees' health, may lead to reduced absenteeism and sick leave, while favoring increased productivity (14, 15).

Although some controlled and well-designed studies have found that workplace-based physical activity interventions can improve general health, physical activity levels (14, 16), weight status (17) and may have positive effects on eating behavior among employees (18); a recent systematic review identified some limitations of such interventions, due to large inter-individual heterogeneity (19). At the same time, a recent study conducted in 2017, underlined the beneficial effects of worksite physical activity programs proposed to tertiary employees on overall health (20). Although this pilot study was the first to our knowledge to enroll both experimented (active individuals, already regular users of their companies' physical facilities) and novice (inactive before the intervention) participants, further studies are now needed using larger sample sizes and more objective methods. Moreover, while the studies conducted so far mainly focused on increasing the level of physical activity of workers, tertiary employees remain highly sedentary due to the static nature of their work, which might have deleterious effects, independently of their physical activity levels. Some interesting studies effectively suggest that long periods of sedentary behaviors increase the risk of cardiovascular diseases, type 2 diabetes, some cancers and obesity, among other conditions, even in individuals reaching recommended levels of physical activity (2).

While it remains evident that workplace interventions have to be conducted to favor healthy active living among tertiary employees, the sedentary nature of such professional activities must be considered. The first aim of the present study was to compare overall health indicators among physically active and inactive tertiary employees, showing a high level of sedentariness. Secondly, we assessed the effects of a 5-month physical activity workplace intervention on overall health indicators between sedentary previously active and newly active tertiary employees.

METHODS

Participants and Design

A total of 193 office employees (tertiary workers; 83 females, 110 males; age: 44.2 ± 9.8 years; weight: 72.6 ± 14.7 kg; BMI: 24.5 ± 3.8 kg/m²) took part in this quasi-experimental study. Participants were approached and recruited through the manufacturer internal network, thanks to various informative announcements to the employees. After a medical inclusion to control for their ability to complete the whole study, anthropometric measurements and body composition were assessed, aerobic fitness, muscle capacities, well-being as well as quality of life and health perception were measured (T0). The participants followed then a 5-month on-site physical activity intervention and all these measures were replicated by the end of the intervention (T1). All the participants received information sheets and signed consent forms as requested by ethical regulations. To be included the participants had to: (i) be tertiary employees; (ii) show no contraindications to physical practices; (iii) be free of any medication that could interfere with the study outcomes. Employees who showed a regular participation in their worksite physical activity program for the last 2 years were classified as active while the others were classified as inactive. Their physical activity level was also confirmed through a self-reported physical activity questionnaire (21, 22) based on the World Health Organization's Physical activity guidelines (at least 150 min of moderate to vigorous activity per week) (23). All the participants received information sheets and signed consent forms as requested by ethical procedures. This study has been reviewed and approved by our local ethical authorities (Local Human Protection Committee - CPP SUD EST VI / CNIL).

On-Site Physical Activity Intervention

Active and inactive groups were requested to take part in two to three training sessions per week, within their worksite training program. Each session lasted 45 min minimum, alternating between muscle-strengthening and cardiorespiratory exercises (one of each per week), supervised by a professional for a duration of 5 months. The program proposed 18 different physical activities such as muscle strengthening, stretching, cardiorespiratory or team sports. The participants were asked to perform at least one muscle-strengthening (weights machines) and one cardiorespiratory session (Latin dance, step, bike, fight exercise...) per week. Compliance was controlled by a computerized access to the sport facilities.

Anthropometric Measurements and Body Composition

A digital scale was used to measure body mass to the nearest 0.1 kg, and barefoot standing height was assessed to the nearest 0.1 cm using a wall-mounted stadiometer. Both body mass and height were obtained at the same time of the day for the same subject, and not in a fasting state. Body Mass Index (BMI) was calculated as body mass (kg) divided by height squared (m^2). Body Composition was assessed by bioelectrical impedance analysis, performed with the Tanita MC780 multi frequency segmental body composition analyzer. This analyzer consists in a stand-alone unit where the subject has to step on bare foot (standard mode). Information concerning the subject (age, gender, and height) is entered by the researcher. Once body mass has been assessed by the scale, the subject has to take grips with both hands (alongside his body) during the impedance measure (Hand to foot BIA). A full segmental analysis is performed in less than 20 s. Total body fat, total fat-free mass and body water were reported by the researcher into an excel sheet for statistical treatment. The newly developed BIA analyzer has been recently validated in healthy adults (24).

Well-Being, Quality of Life and Health Perception

Well-being and quality of life at work were assessed using a newly developed questionnaire ("worksite well-being and quality of life questionnaire") especially designed for occupational health studies. The participants were asked to rate statements describing their well-being at work using visual analog scales ranging from "not at all" to "absolutely" (i.e., "I'm actually feeling distressed while at work"). This questionnaire has been recently validated in a similar population (25).

All participants were also asked to complete a short self-administered questionnaire specifically designed to explore their perception of health ("health perception scale"). Six criteria were investigated: (1) perceived physical fitness, (2) perceived ideal weight, (3) perceived healthy balanced diet, (4) perceived sleep quality, (5) perceived stress level, and (6) perceived general health. A10-point scale from 1 (not at all) to 10 (very much) was used to assess each item. The six individual scores were computed to obtain a global score for health perception. This questionnaire has been previously validated in adults (26).

Aerobic Fitness

The step test was performed on a stool of 16.25 inches (41.3 cm) for men and 11.8 inches (30 cm) for women for a total duration of 6 min at the rate of 24 cycles per minute, which was set by a metronome. Participants were asked to wear a heart rate monitor (Polar Electro Inc, Lake Success; USA) during the test and heart rate was recorded at the end of the 6 min, 30 s and 1 min after completion of the test. This test has been found reliable in healthy subjects and it is highly reproducible (27).

Muscle Capacities

Upper limbs muscle strength was assessed using the handgrip on the dominant hand, as a non-invasive marker of muscle strength of upper limbs, well suitable for clinical use (28). The participants were also asked to perform a maximal number of push-ups (with the knees on the floor) respecting an imposed frequency. The test stopped once they were not able to maintain this rhythmicity or showed difficulties to maintain the correct position (29, 30). Counter Movement Jump (CMJ) was used to assess lower limb muscle strength using the Optojump technology (Microgate SRL, Rome, Italy) (31). The Shirado test was used to assess the static endurance of the abdominal muscles (32) and the Sorensen test to assess back strength and endurance for all the muscles involved in the extension of the trunk (33).

STATISTICAL CONSIDERATIONS

Sample size has been estimated in order to compare overall health indicators as fat mass percentage among physically active and inactive tertiary employees showing a high level of sedentariness. According to our previous work (20) and to Cohen's recommendations (34) who has defined effect-size bounds as: small (ES: 0.2), medium (ES: 0.5) and large (ES: 0.8, "grossly perceptible and therefore large"), we calculated that a minimum of 185 participants would allow to highlight an effect size equal to 0.5 for a two-tailed type I error at 5%, a statistical power of 90% and a ratio 60–40% for inactive/active employees. All analyses were performed using Stata software (version 13, StataCorp, College Station, TX). Statistical analyses were done for a two-sided type I error of a = 5%. Baseline subject's characteristics were presented as the mean ± standard deviation (*SD*) or the [median interquartile range] for continuous data (assumption of normality assessed by using the Shapiro-Wilk test) and as the number of patients and associated percentages for categorical parameters. Quantitative variables were compared (at each time-point evaluation T0 and T1) between independent groups (active vs. inactive tertiary employees) by Student *t*-test or Mann-Whitney test if conditions of *t*-test were not respected (normality and homoscedasticity analyzed using Fisher-Snedecor test). Comparisons between independent groups were done by Chi-squared or when appropriate by Fischer-exact test for categorical variables. To analyze repeated correlated data, the evolution of variations between the beginning and the end of the study was calculated for each parameter. Then, random-effects models were performed to study fixed effects as group (noted intergroup evolution of variations in **Tables 1**, **2**), time-points evaluation and their interaction taking into account between and within subject variability. The normality of residuals was checked for all models. A sensibility analysis was performed to measure the possible impact of missing data (notably imputation of missing data). Results and practical conclusions were analogous (data not shown).

RESULTS

A total of 193 middle and upper classes office workers took part in the study; 84 females and 110 males with an average age of 44.2 ± 9.8 years, an average weight and BMI of 72.6 ± 14.7 kg and 24.5 ± 3.8 kg/m² respectively. At baseline (T0), 98 and 95 participants composed the inactive and active groups respectively against 71 and 73 at the end of the intervention (T1).

Figure 1 illustrates the dropout rate observed during the 5-month workplace program. 22% of all subjects dropped out before the end of the intervention, with a higher rate observed in the initially active employees: 20% did not complete the whole study against 27% in the inactive sample ($p < 0.05$).

Table 1 details the results for anthropometric characteristics and body composition, while **Table 2** presents the participants' functional characteristics, well-being and health perception. There was a statistically significant difference for push-ups ($p \leq 0.001$; $p \leq 0.01$ respectively), Sorensen test ($p \leq 0.001$), fat

TABLE 1 | Intra- and inter-group results for anthropometry and body composition.

		Inactive	Active	*I vs. A*
Fat mass (%)	T0	24.8 ± 7.5	21.7 ± 7.1	*p = 0.0032*
	T1	22.8 ± 6.9	20.8 ± 7.3	*p = 0.0722*
	T0 vs. T1	*p < 0.001*	*p < 0.001*	
Fat-free mass (kg)	T0	52.5 ± 11.3	53.6 ± 10.7	*ns*
	T1	54.5 ± 10.9	52.7 ± 9.9	*ns*
	T0 vs. T1	*ns*	*ns*	
BMI (kg/m²)	T0	25 ± 4.6	24.1 ± 3.2	*ns*
	T1	24.9 ± 3.9	23.7 ± 3.1	*p = 0.0864*
	T0 vs. T1	*ns*	*ns*	
WC (cm)	T0	92 ± 15.3	87.5 ± 12.3	*p = 0.0264*
	T1	92 ± 13.4	87 ± 12.1	*p = 0.0287*
	T0 vs. T1	*ns*	*ns*	

BMI, Body Mass Index; WC, Waist Circumference; T0, baseline; T1, end of the 5-month program; I, Inactive; A, Active.

TABLE 2 | Intra- and inter-group results for functional tests, health perception and well-being.

		Inactive	Active	*I vs. A*
Health perception	T0	51.2 ± 15.1	61.3 ± 14.3	*p < 0.001*
	T1	59.1 ± 14.7	62.5 ± 12.7	*ns*
	T0 vs. T1	*p < 0.001*	*ns*	
Worksite well-being	T0	7.34 ± 1.4	7.3 ± 1.3	*ns*
	T1	7.3 ± 1.2	7.4 ± 1.3	*ns*
	T0 vs. T1	*ns*	*ns*	
Rest heart rate (bpm)	T0	71.3 ± 11	67.2 ± 11.6	*ns*
	T1	73.5 ± 10.5	68.3 ± 10.3	*ns*
	T0 vs. T1	*ns*	*ns*	
Heart rate (bpm)	T0	150.4 ± 20.2	147.9 ± 19.9	*ns*
	T1	141.1 ± 18.3	135.6 ± 17.3	*p = 0.0698*
	T0 vs. T1	*p = 0.0029*	*p < 0.001*	
Heart rate +30 (bpm)	T0	126 ± 26.6	128.3 ± 22	*ns*
	T1	127.8 ± 19.3	116.9 ± 19.2	*p = 0.0329*
	T0 vs. T1	*ns*	*p < 0.001*	
Heart rate +60 (bpm)	T0	116 ± 20.8	112.4 ± 22.4	*ns*
	T1	111.3 ± 21.3	103 ± 18.4	*p = 0.0236*
	T0 vs. T1	*ns*	*p < 0.001*	
CMJ (cm)	T0	24.6 ± 7.7	23.6 ± 7.1	*ns*
	T1	26.7 ± 7.6	24.4 ± 8.9	*ns*
	T0 vs. T1	*p = 0.0256*	*ns*	
Handgrip (kg)	T0	24.6 ± 7.7	23.6 ± 7.1	*ns*
	T1	41.8 ± 10.7	40.3 ± 11.1	*ns*
	T0 vs. T1	*p = 0.0035*	*p = 0.0082*	
Puch-ups (rep)	T0	22.8 ± 14.4	36.5 ± 19.2	*p < 0.001*
	T1	29.4 ± 15.4	39.8 ± 18	*p = 0.0014*
	T0 vs. T1	*p < 0.001*	*ns*	
Shirado (s)	T0	173.1 ± 77.7	181.8 ± 50.9	*ns*
	T1	184.1 ± 82.2	174.3 ± 52	*ns*
	T0 vs. T1	*ns*	*ns*	
Sorensen (s)	T0	101.2 ± 56.9	159 ± 41.6	*p < 0.001*
	T1	112.3 ± 54.2	161.2 ± 47.7	*p < 0.001*
	T0 vs. T1	*ns*	*ns*	

CMJ, Counter Movement Jump; ST, step test; HR, heart rate; T0, baseline; T1, end of the 5-month program; I, Inactive; A, Active.

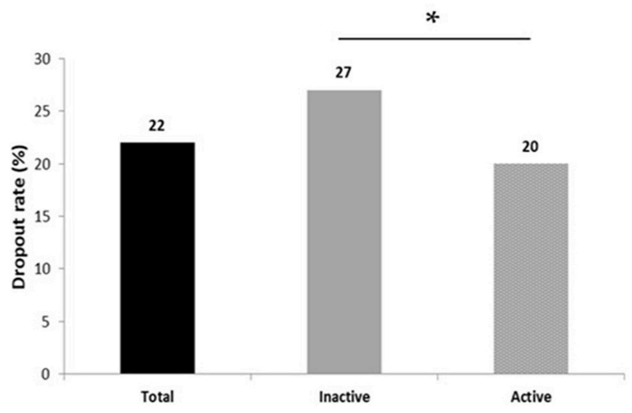

FIGURE 1 | Dropout rates to a 5-month workplace physical activity program between initially active and inactive tertiary employees (*$p \leq 0.05$).

mass ($p \leq 0.01$; tendency respectively) and waist circumference ($p \leq 0.05$) between active and inactive at T0 but also at T1. **Table 2** also highlights a significant difference for health perception at T0 between active and inactive participants ($p \leq 0.001$), but this difference no longer exists at T1. No significant change in worksite well-being, rest heart rate, CMJ, Shirado test, fat-free mass or BMI was observed during the study. There was a time effect for the inactive group which demonstrates significant progressions between T0 and T1 for health perception ($p \leq 0.001$), and CMJ ($p \leq 0.01$). In contrast, the two groups significantly improved their results for handgrip ($p \leq 0.01$), push-ups (inactive: $p \leq 0.001$ and active: $p \leq 0.05$), fat mass ($p \leq 0.001$) and their heart rate post exercise (inactive: $p \leq 0.01$ and active: $p \leq 0.001$) between T0 and T1.

Table 3 details the results of the amplitude of the variations obtained between T0 and T1. Health perception ($p \leq 0.001$), performances at the Sorensen test ($p \leq 0.05$), Shirado test (tendency) and BMI (tendency) all show a significantly higher progression in the inactive compared with the active groups. The variations observed between T0 and T1 were not found significantly different between groups for worksite well-being, CMJ, handgrip, push-ups, fat mass, fat-free mass and waist circumference.

DISCUSSION

The main aim of the present study was to compare overall health indicators between active (above recommended levels of physical activity) and inactive (below recommended levels) employees with high and similar levels of worksite-induced sedentariness. According to our results, BMI, fat-free mass, lower and upper limbs muscle capacities (CMJ and handgrip) and aerobic capacities are not different between active and inactive tertiary employees who both spend about 7.5 h per days seated in front of computers (approximately 37.5 h/week). This is to our knowledge the first study that questions the effect of a high level of sedentariness on health and fitness indicators among physically active and inactive workers.

While public health strategies have been developed to increase individuals' physical activity levels over the last decades, more concerns are expressed today regarding the progression of sedentariness. Indeed, it is now clear that physical activity and sedentary behaviors are two different constructs that have independent effects on health (35). This is particularly important since sedentariness has become one of the largest public health concerns, being nowadays recognized as one of the main causes of preventable premature mortality. Although worksites have been identified as ideal settings to favor physical activity among workers (9), the "tertiarisation" of our societies and industries has been favoring sedentariness, with employees spending now most of their daily time seated in front of computers. While most of the available studies have been evaluating the levels of physical activity of tertiary employees (36), their time spent seated and/or in front of a computer screen (37), or have been independently looking at the effect of physical activity programs (38) or interventions aiming at reducing sedentary time (39), we did not find any work comparing fitness parameters between physically active and inactive tertiary employees who are characterized by a high level of sedentariness.

In their study, Ko et al. compared the incidence of metabolic risk factors and the prevalence of metabolic syndrome between white collars divided in physical activity tertiles (40). According to their results, workers with the lowest physical activity levels present higher waist circumference, increased triglycerides concentrations, higher HDL-C concentrations and a higher risk for metabolic syndrome (40). Unfortunately, their data do not allow the classification of their participants as active or inactive in regards to physical activity guidelines, and information regarding sedentary behaviors is missing, as well as details regarding the exact occupational activity of their participants (40). More recently, Browne et al. conducted a cross-sectional study among about 500 sedentary tertiary employees, hypothesizing that sedentary occupational workers who meet physical activity recommendations (without precising the guidelines used) present lower risks for metabolic syndrome than inactive ones (41). Their results point out that active workers show lower odds for abdominal obesity, elevated blood pressure, reduced high-density lipoprotein cholesterol and overall metabolic syndrome, after adjustments for age, working hours, body mass index, and tobacco use (41). The significantly higher fat mass percentage and waist circumference observed in our inactive group are in line with these results. Although these studies tend to suggest that in employees who spend most of their daily time sedentary, physical activity has beneficial effect on their metabolic health, we missed finding any data related to physical and overall health fitness.

Not only objective health and fitness indicators were assessed in the present work, employees' self-perception of their overall health and work-related well-being were investigated. Although active workers show a significantly greater score for overall health perception, worksite wellbeing was not significantly different compared with inactive employees. Although this might suggest that physical activity levels might not be associated

TABLE 3 | Intergroup evolution of variations between the beginning and the end of the study.

	Inactive		Active		p
	mean sd	**var**	**mean sd**	**var**	
Health perception	20.2 ± 35.4	13.6 [−2.7;35.1]	3.7 ± 21.2	1.5 [−11;8.4]	$p < 0.001$
Worksite well-being	2 ± 21.3	1.4 [−11.4;14.3]	1.8 ± 17.2	−0.06 [−6.4;8.3]	
CMJ (cm)	5.2 ± 14	3.2 [−3.8;9.9]	3.9 ± 21.8	3.3 [−1.6;12.2]	
Handgrip (kg)	3.4 ± 8.7	2.9 [−1.5;9.1]	4.1 ± 10.9	3.2 [−3.1;10.3]	
Puch-ups (rep)	29.5 ± 65.3	16.4 [0;40]	50 ± 230.2	6 [−5.9;26]	
Shirado (sec)	20.5 ± 73	0 [−14.3;28.7]	−2.9 ± 22.4	0 [0;0]	$p = 0.0743$
Sorensen (sec)	35.4 ± 119.8	0 [0;28.2]	0.08 ± 21.7	0 [0;0]	$p = 0.0341$
Fat mass (%)	−4.2 ± 9.3	−4.1 [−9.6;−0.4]	−3.4 ± 8.9	−2.7 [−7.8;3.3]	
Fat-free mass (kg)	0.8 ± 2.6	1 [−0.4;2.4]	0.7 ± 3.4	0.7 [−0.5;2.4]	
BMI (kg/m²)	−0.6 ± 3	−0.4 [−2;0.8]	0.1 ± 2.4	0.4 [−1.3;1.7]	$p = 0.0612$
WC (cm)	−0.2 ± 3.6	-0.4 [−2.3;1.5]	0.05 ± 3.6	−0.1 [−2.5;2.8]	

BMI, Body Mass Index; WC, Waist Circumference; CMJ, Counter Movement Jump; T0, baseline; T1, end of the 5-month program; I, Inactive; A, Active.

with employees' work-related satisfaction and comfort, some recent studies suggest that tertiary employees' wellbeing might be related to sedentary behaviors, which may explain our results since both active and inactive workers present here at least 7.5 h of sedentary time per day (42). Such results are definitely of importance for both workers and employers, since work-related wellbeing has been clearly identified as a major predictive factor for prolonged or future sickness absence (43).

The second aim of the present work was to assess the effects of a 5-month worksite structured and monitored physical activity program among initially inactive and active employees (already regularly using the companies' physical facilities for the last 2 years). While the majority of the published papers in the field assesses the effects of physical educations, encouragement and motivational strategies (39, 44) walking meetings (45) or sedentary breaks (46), less studies have been conducted implementing structured aerobic and resistance exercise sessions (20, 47). In 2009, Pedersen et al. conducted a 1 year randomized controlled trial questioning the effects of resistance training and all-round physical exercise sessions performed within workplaces (1 h/ week during working hours) on tertiary employees health indicators (47). Their results showed significant reductions of cardiovascular and metabolic syndrome-related risk factors as well as musculoskeletal pain symptoms, concomitantly with minor increases in physical capacities. The physical activity levels of the participants was however not considered. In the present study, the participants were asked to perform 2 to 3 exercise sessions per week, composed of resistance and aerobic exercises, in one of the physical activity facilities proposed by their companies. According to our results, while numbers of health and fitness indicators were improved by the program in our initially inactive subsample, active individuals also show improvements. While health perception and counter movement jumps were significantly improved in the inactive group only, the heart rate response to our aerobic test, the handgrip performance, the maximal number of push-ups, as well as the percentage of fat mass was significantly improved in both groups. Interestingly, the heart rate recovery 30 s and 1 min after the aerobic test were improved in the experienced group only. These results suggest that while such a physical activity intervention has beneficial effects in initially inactive employees, it continues to favor positive adaptations in active ones. These results are in line with a previously published pilot study, suffering from reduced sample size but already suggesting the interest of worksite exercise programs among tertiary employees, whatever their initial physical activity level (20).

Although the present study provides main insights regarding the importance of considering both sedentary and physical activity levels when it comes to evaluating tertiary employees' health indicators, and underlines the beneficial effects of structured on-site physical interventions among both active and inactive workers, our results also point out the necessity to consider the employees' adherence rate to such programs. Indeed, 1 out of 5 participants did not complete the whole intervention, which must definitely be considered by stakeholders and investigators who must try to understand and identify the potential undelying reasons. This 20% dropout rate observed here, is in line with what is rarely discussed but usually observed in other similar studies. In their study, Jakobsen et al. asked tertiary employees to exercise 5 times a week (10-min sessions) for 10 weeks and observed a similar dropout rate of 22% (48). During their 1 year trial, Pedersen et al. obtained a 48% dropout rate among office workers who exercised 3 times a week (47) and in our previous pilot work, 30% of the enrolled participants were found to quit before the end of the intervention (20). While such high dropout rates are usually observed, the profile of these participants remains under-explored. Although further studies are needed, specifically designed to address this question, our results, as illustrated by the **Figure 1**, tend to suggest that the initial physical activity level of the enrolled employees should be considered with a total of 20% of non-compliant being observed in the initially active sub-sample against 27% among the initially inactive one. This also highlights the fact the least active employees–and therefore those who need it the most—are those who are at highest risk to drop out from such worksite PA programs.

Our results should clearly be interpreted in light of some limitations. The sample size might be considered as one of the limitations, underlying the difficulty to recruit volunteers for such interventions, reinforcing the need for deeper explorations of the potential specific profile of employees interested in workplace physical activity programs. The use of field testing to assess employees' physical fitness might also be a limitation, and more objective methods could be used, such as ergometers and direct methods to assess their aerobic capacities (laboratory-based maximal aerobic testing). Moreover, the use of BIA to assess body composition is not as accurate as dual-x-ray absorptiometry for instance; it composes however one of the best alternatives for studies enrolling large samples and remains a reliable and validated tool in healthy adults as previously described (24).

To conclude, the present study suggests that improvements in some health and fitness indicators might not be found among active tertiary employees, compared with inactive ones, which might be due to the high level of sedentariness characterizing their occupational task. This result clearly calls for worksite-based interventions not only focusing on physical activity but also, and perhaps most importantly, trying to break down sedentary time. Our results also confirm that structured exercise interventions implemented with workplaces, improve health and fitness among both initially physically inactive and active tertiary workers, questioning however the profile of workers who are willing to be compliant to on-site physical interventions.

AUTHOR CONTRIBUTIONS

PG and BP analyzed the data used in the manuscript, PD and JF participated in the project design. PG, DT, FD, and MD wrote and reviewed the paper.

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Longitudinal Follow-Up of Physical Activity During School Recess: Impact of Playground Markings

Georges Baquet, Julien Aucouturier, François Xavier Gamelin and Serge Berthoin*

University of Lille, University of Artois, University of the Littoral Côte d'Opale, EA 7369 - URePSSS - Unité de Recherche Pluridisciplinaire Sport Santé Société, Lille, France

To promote physical activity (PA) among children, few studies have reported long-term effects of playground marking during school recess. The aim of this study was to investigate the impact of a playground design on children's recess PA across 12 months and to evaluate the influence of covariates on the intervention effects with accelerometry data. Two hundred and eighty-three children (aged 6–11 years) were selected from 3 elementary schools. Two experimental schools received a recess-based intervention; the third one served as a control group. The design of playgrounds was based on a multicolored zonal design. Children's PA was measured with a uniaxial accelerometer twice a day (morning and afternoon recess) during a 4-day school week. Times spent below and above different PA levels, varying from sedentary (SED, <1.5 METs), light PA (LPA, < 4 METs), and from moderate to very high (MVPA, ≥ 4 METs) were calculated before and after 6 and 12 months intervention. A three level (time, pupil, school) multilevel analysis was used to control the intervention effect across time on SED, LPA, and MVPA. The playground intervention was effective after 6 months for LPA (+2.5%, CI 0.65/4.29, $P < 0.01$) and after 12 months for MVPA (+3.1%, CI 0.62/5.54, $P < 0.01$). Moreover, negative non-significant intervention effects were found for SED and LPA. Baseline PA and sex were significant covariates to the contrary of body mass index and age. Playground markings intervention can modify positively long-term school recess total PA.

Keywords: children, accelerometry, behavior, multilevel analysis, intervention

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Edited by:
Frederic Dutheil,
Centre Hospitalier Universitaire de Clermont-Ferrand, France

Reviewed by:
Evangelia Nena,
Democritus University of Thrace, Greece
Georgios Merekoulias,
University of Patras, Greece

****Correspondence:***
Georges Baquet
georges.baquet@univ-lille.fr

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INTRODUCTION

An insufficient level of physical activity (PA) is a major problem in industrialized countries. Sedentary activity appears early in life (1) and therefore the promotion of physical activity has become necessary in childhood. Habitual PA level of an adult is also partly determined by the level of PA in childhood (2). Faced with growing health problems, including the increased prevalence of overweight and obesity, a consensus has been established for children and adolescents, suggesting 60 min of at least moderate daily PA and incorporating three times a week intense PA (3, 4).

In 2001, Sallis et al. (5) concluded that school environments with high levels of supervision and improvements stimulated girls and boys to be more physically active. Since children spend a substantial time at school, its role in the development of related PA behaviors is very important. Physical Education sessions and recess times are ideal settings to promote PA times because most children attend school and thus can be targeted (6). Habitual PA during recess determines in part the level of PA in children (7), and specific amenities playgrounds allowed a significant increase in habitual physical activity of children (8). These playground markings or additional play equipment allowed to improve total PA and moderate-to-vigorous PA (MVPA) during recess (9, 10). Ridgers et al. (10) have investigated the effect of such a making over time, showing an increase of children's morning and lunch MVPA and vigorous PA (VPA). However, this effect was decreased between 6 and 12 months, highlighting potential confounding variables that influence the intervention effect. Moreover, light PA (LPA) and sedentary activity were not investigated. In children, MVPA and sedentary behavior are independent (11) and then can be influenced by different factors (12). Few data currently exist on correlates of MVPA and sedentary behavior during recess over time. Van Kann et al. (13) have reported that implementation of a multicomponent schoolyard PA intervention did not result in 12 months changes in MVPA. A larger proportion of recess time was spent in light physical activity, which was most likely the result of a shift from sedentary behavior to light physical activity. However, PA was only monitored during the morning recess, which reflects only one of three major PA occasions during a school day, morning, lunch time, and afternoon recess. Further research on recess intervention is needed to examine concerning the effectiveness and feasibility of the effects of interventions in this context on sedentary behavior and PA, PA can be of light, moderate or vigorous intensity.

The purpose of this study was to follow-up the effects of a school-based playground markings intervention on children's recess physical activity levels over 12 months and to highlight factors associated with sedentary behavior and different levels of PA.

MATERIALS AND METHODS

Participants

Three elementary schools located in the same geographical area in the north of France were recruited to participate in the study. There was no ethnic distribution of children. The elementary schools were representative of the Lille suburban area, had similar playground space (around ∼1,300 and 1,500 m^2) and were randomly assigned to experimental and control groups. The flow of children and schools through the study is shown in **Figure 1**. Three hundred and twenty-six children (162 girls and 164 boys) aged 6–11 years old and their guardians gave informed written consent to participate. The experimental group (EG) included 202 children (111 girls and 91 boys) and the control group (CG) 124 children (51 girls and 73 boys). The study was designed in accordance with ethical standards of the Helsinki Declaration of 2008 and received approval from the "Comité Consultatif de Protection des Personnes en Recherche Biomédicale de Lille."

Anthropometric Measurements

Height was measured to the nearest 0.1 cm with a wall stadiometer (Vivioz Medical, Paris, France) and body mass was measured to the nearest 0.1 kg with a calibrated electronic balance (Tanita TBF 543, Tanita Inc, Iokyo, Japan). Body Mass Index (BMI) was calculated according to equation: BMI = body mass (kg)/height ^{2} (m^2). Child weight status was based on BMI percentile cut off points (normal weight: 5%–<85%; overweight: 85% and above) according to WHO (14).

Physical Activity Monitoring

Children's PA was assessed with a uniaxial accelerometer (The ActiGraph®, Manufacturing Technologies, Inc., model GT1M), during school recess time (morning, 10–10:15 a.m. and afternoon, 3–3:15 p.m.) only, over 4 school days (Monday, Tuesday, Thursday, Friday). The ActiGraph device facilitates the measurement of human movement (frequency and intensity) over a user-specified time epoch. In this study, the epoch was set at 2 s (15). Accelerometers were distributed in the morning when the children arrived at school and were returned after the afternoon recess period. Data were downloaded for statistical analysis.

Interventions

The experimental schools received specific playground markings with thermoplastic girdles (Magical Markings, UK), which cost 15,000 Euros per school. The intervention playground environment was based on the sporting playground zonal design (16). This involved a playground division into three specific games (17) and three color-coded areas: (1) a yellow "quiet zone" with non- active games (e.g., chess and drafts), (2) a blue "multi-activity" area for physical fitness and motor skills improvement, and (3) a red 'sports' area (e.g., football, basketball). Children with their teachers were associated to the design of the playground. Fun trails and dens, hopscotch or designs of dragons, clock faces, pirate ship, snakes, or ladders were evenly spaced throughout the playground area. Prior to the intervention, the use of portable play equipment was not allowed by the intervention and control schools. Play equipment (e.g., rackets, balls, huge dies chess, scarfs, hockey sticks…) was provided in the intervention school playground areas by the schools following the redesign (18). Schoolteachers supervised morning and afternoon recess periods.

Data Reduction

Files with missing data were deleted. Times spent below and above different PA levels, varying from sedentary (SED, <1.5 METs, light PA (LPA, <4 METs), moderate PA (MPA, <6METs, to vigorous PA (VPA, 6 ≥METs) and from moderate to very high (MVPA, ≥ 4 METs), were calculated before and after 1, 6, and 12 months intervention. ActiGraph outputs analyzed following the procedures of Trost et al. (19). To compare the time spent in different PA levels between groups, PA time is reported as the percentage of total recess time (morning and afternoon).

Statistical Analysis

Data collected from 43 children (21 girls and 22 boys) who had withdrawn from the study or left the school were rejected. Children who were absent from school on the day of testing or experienced monitor problems were recorded as missing data at that point. Finally, 283 children (141 girls and 142 boys) were retained for the statistical analysis. The experimental group included 185 children (99 girls and 86 boys) and CG 98 children (42 girls and 56 boys). Independent *t*-tests were conducted to

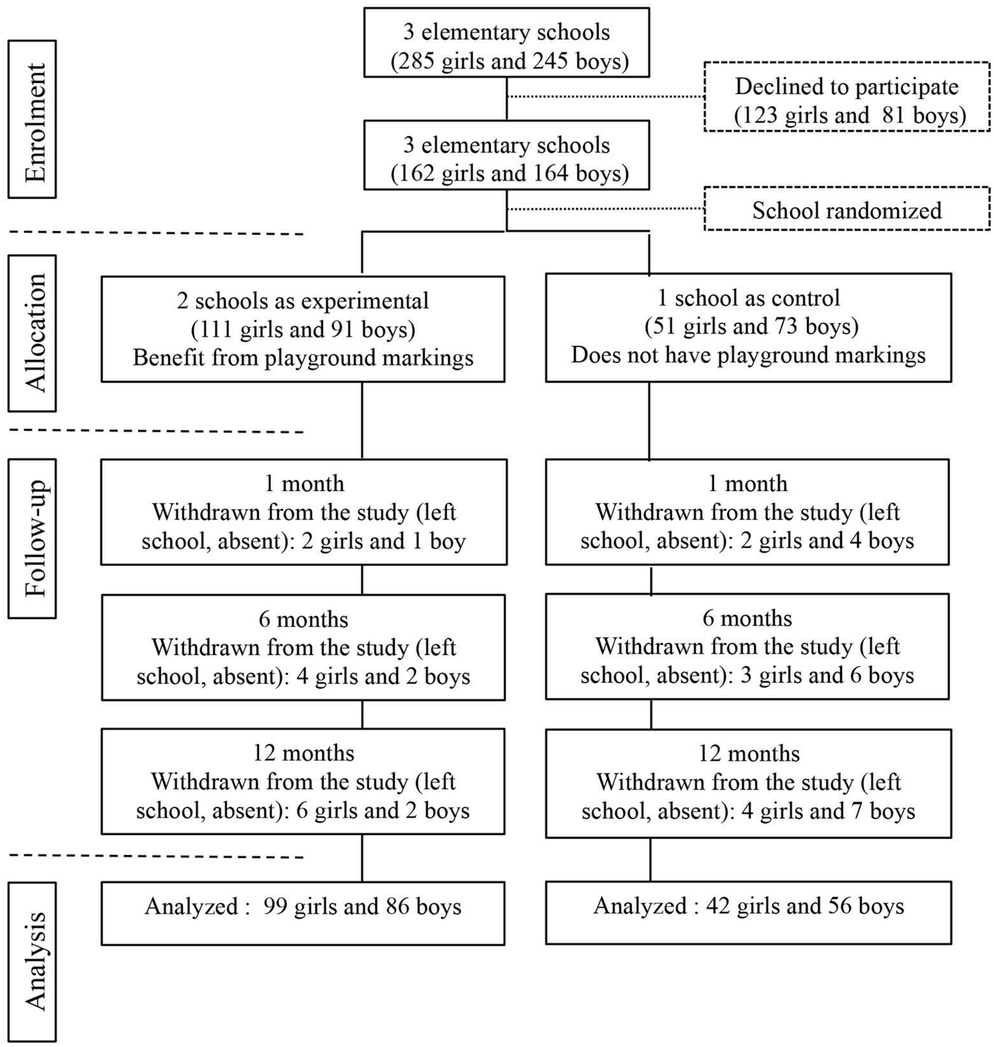

FIGURE 1 | Enrolment, allocation, follow-up, and analysis in the school-based intervention. Measurements were taken at baseline, 1, 6, and 12 months post-intervention.

examine gender and intervention group differences in baseline variables. All values are expressed as mean ± standard deviation (mean ± SD).

As children's physical activity measurements are not independent of each other in the same environment, a multilevel model was used to take into account this dependency and to determine the effects of the playground intervention (20). To analyze the hierarchical nature of physical activity measurements, a three level (time, pupil, school) multilevel analysis was used to control the intervention effect across time on SED, LPA, MPA, VPA and MVPA. Timing of the follow-up measurement (1, 6, 12 months; level 1), pupils (level 2), and schools (level 3) served as the grouping variables. Potential confounding variables were added to the model as they may influence the effect of intervention. Time (1, 6, 12 months) was level 1 variable and sex, age, baseline physical activity, and BMI group (normal, overweight, obese) were level 2 variables. The intervention term was constructed using a dummy variable, where "0" indicated a control group school, and "1" indicated an intervention school.

Data were analyzed using MLwiN 2.30 software (University of Bristol, UK). In all cases, threshold for significance was set at $p < 0.05$.

RESULTS

Age, anthropometric data and baseline physical activity levels of the children are presented in **Table 1**. Physical activity data during intervention were displayed in **Figures 2A–C**. The results of the multilevel analysis are reported in **Table 2**.

At Baseline and at Follow-Up

At baseline, no significant differences were found on the anthropometric data for the boys and the girls. EG boys engaged in lower levels of MVPA during recess than CG boys ($p < 0.05$)

TABLE 1 | Descriptive baseline and anthropometric and physical activity data at baseline.

	Boys		Girls	
Baseline	**EG (n = 86)**	**CG (n = 99)**	**EG (n = 56)**	**CG (n = 42)**
Age (years)	8.5 ± 1.2	8.1 ± 1.8	8.1 ± 1.1	8.1 ± 1.6
Height (m)	1.3 ± 0.1	1.3 ± 0.1	1.28 ± 0.1	1.3 ± 0.1
Body mass (kg)	31.1 ± 7.7	28.3 ± 6.9	28.2 ± 6.5	27.9 ± 6.4
BMI (kg.m^{-2})	17.5 ± 3.0	16.7 ± 2.1	17.0 ± 2.4	16.9 ± 2.0
% SED	35.6 ± 10.2	38.5 ± 10.6	45.0 ± 10.6	44.1 ± 8.6
% LPA	32.2 ± 6.0	33.6 ± 6.2	32.6 ± 5.4	33.1 ± 4.6
% MVPA	32.1 ± 8.9*	27.9 ± 8.00	22.4 ± 8.0	22.9 ± 7.6

*EG, experimental group; CG, control group; BMI, body mass index; SED, sedentary; LPA, light physical activity; MVPA, moderate to vigorous physical activity; *significantly different from CG boys at $p < 0.05$.*

while no significant difference was found between EG and GG in girls for PA levels.

Intervention Effect on Change in SB, LPA, and MVPA

Table 2 shows the effect of the intervention on SED, LPA, and MVPA at the 6 and 12 months follow-up measure. A significant positive intervention was found for LPA and MVPA. Children from EG engaged in 3.36% (CI: 1.05–5.94, $p < 0.001$) more MVPA than CG after 12 months of intervention and in 2.47% (CI: 0.65–4.29, $p < 0.01$) more LPA than CG after 6 months of intervention. No significant intervention was found for SED.

Statistical analyses showed that sex was a significant negative variable of LPA and MVPA during the intervention. Boys were engaged in significantly more MVPA (5.44%, CI: 4.14–6.73, $p < 0.001$) while girls spent significantly more time in SED (7.26%, CI: 5.53–8.98, $p < 0.001$).

Body mass index and age were not significant predictors for more or less SB, LPA, and MVPA after intervention.

DISCUSSION

The aim of the current study was to follow-up the effects of a school-based playground markings intervention on children's recess physical activity levels over 12 months using accelerometry data. The school-based playground markings intervention showed an increase in the time spent in MVPA over time. This result is in accordance with previous studies (10, 18–20). An increase in MVPA is in contrast to VanKann's intervention study (13) that showed positive LPA outcomes but no effect on MVPA. In a review, Ickes et al. (21) reported that a variety of recess interventions has been found to be effective in increasing PA. However, the small number of intervention studies does not allow to establish conclusive effects on children's recess PA (22) and most of them lasted less than 12 months. Moreover, due to the short-term nature of these studies, increases in MVPA may be attributable to a "novelty effect" because the playful aspect of markings arouses children's curiosity. However, after 6 months, we can no longer be considered as a "novelty effect."

To our knowledge, few studies have investigated sustained effects of school-based intervention on PA (10, 13, 23). Ridgers et al. (10) demonstrated a positive effect on MVPA and vigorous physical activity (VPA), but the PA levels were lower at 12 months compared with 6 months. The present study showed that time was a significant positive predictor of SED and LPA, but MVPA decreased significantly over time. The strongest impact of the intervention was observed at 12 months for MVPA and 6 months for LPA to the contrary of Ridgers et al. (10). Ridgers et al. (23) underlined the influence of confounding variables on the effect intervention (equipment, temperature, play space per child). Seasons can influence the level of physical activity of children (24). Weather conditions are generally linked to lower PA and higher sedentary, as children, in case of a very rainy, snowy or icy day, stay in classrooms. The present experiment began in April and ended 1 year later, with an intermediate measurement in November (6 months). This may explain the greater impact of the intervention at 12 months rather than at 6 months. In Ridger's paper (10), only the PA data from the morning and lunch recess periods were retained, while this current monitored PA during morning and afternoon recess. The lunch break period is longer and then children spent longer time in MVPA (18, 25, 26). Indeed, in this present study, not all children eat at school (27), which can influence not only their PA level, nature of commuting between school and home and after-meal activities (28), but also those who remain in school during lunch break, have more space on the playground to be active (29). The longer recess after lunch break period also allows to better improvement in PA level notably when organizing children's PA with coaches, while the periods of the morning and afternoon are free.

By the way, Vann Kann et al. (13) underlined the importance to make interventions more understandable, especially by involving coaches simultaneously with new play equipment or playground paintings. They implemented a variety of schoolyard PA interventions. The comprehensiveness of PA interventions might be a key to increase MVPA at school in a sustainable way (30). The nature of intervention is also questionable. They identify what type of intervention most affected the changes in recess SB and PA over time. Physical schoolyard interventions decreased time spent in SB and increased, but not significantly, time spent in LPA and MVPA. This approach showed that the more physical environmental stimuli were implemented, the larger the change in SB. However, the playground stimuli in the present study have not decrease SB but significantly increase MVPA. When implementing painting playgrounds or any material to increase PA levels at school, there is a need to understand how children play during recess and what are their expectations regarding this implementation. In this study, the children contributed to the development of the playground by giving their opinion on the type of game they wanted.

To the contrary of Ridger's study (10), age was not a negative predictor of physical activity during recess. Older children were as active as young children. Younger children as older children seem to benefit to the same manner of the playground spaces. However, we cannot identify children's behaviors and the playground spaces they used. Generally, older boys play soccer during recess and, girls and younger boys were engaged

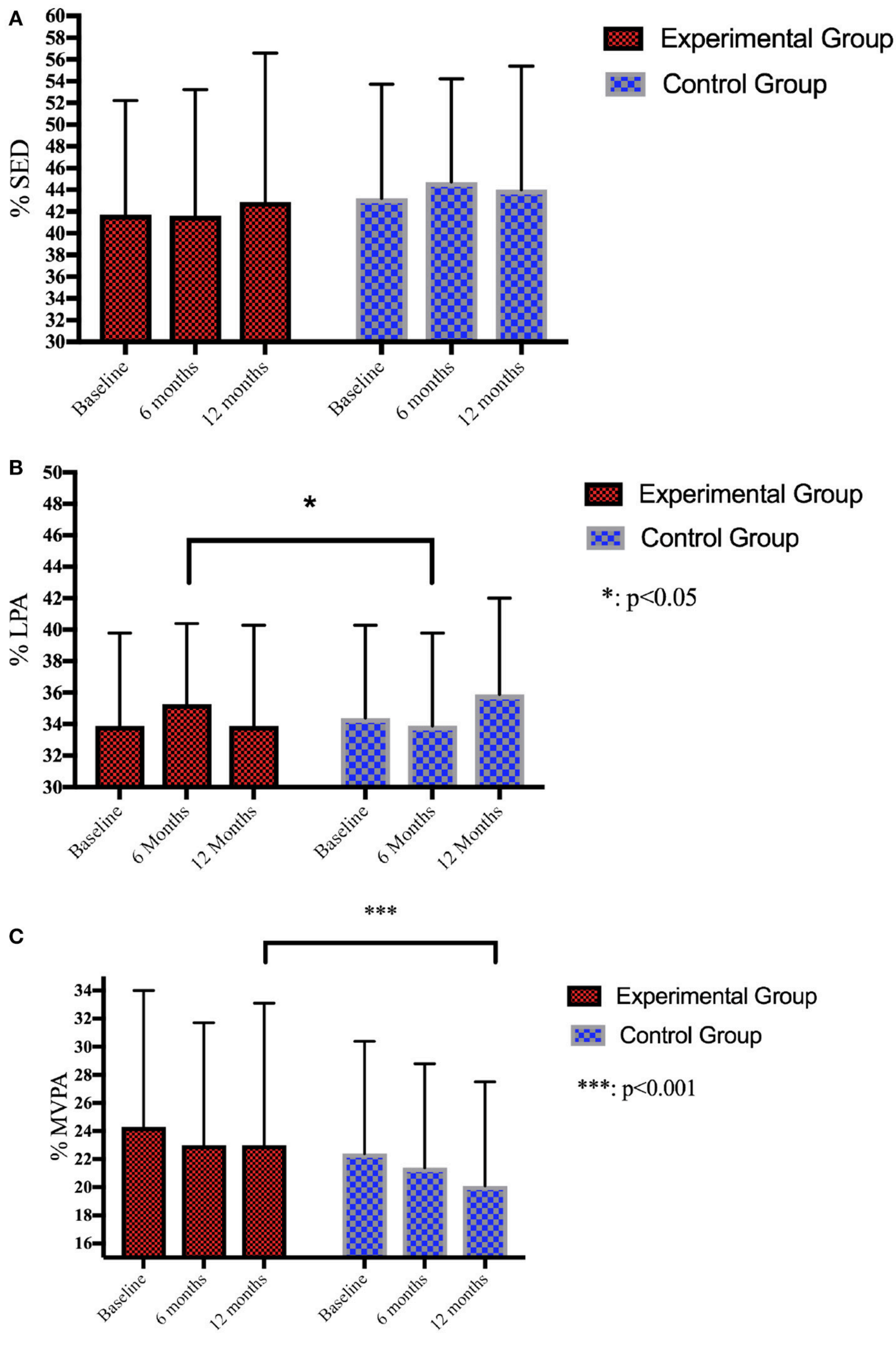

FIGURE 2 | (A) Follow-up of SED during recess over 12 months. **(B)** Follow-up of LPA during recess over 12 months. **(C)** Follow-up of MVPA during recess over 12 months.

in different activities in the remaining playground space. We could not conclude that playground has modified the previous hierarchy. Younger children and girls have certainly benefited from the new playground by accessing more playground spaces. However, playground activities introduced are generally more suited to younger elementary children than older ones. Ridgers et al. (10) conclude that a combination of accelerometry and direct observation to identify children's behaviors and playground spaces they used would give more information. Van Kann et al. (13) have used Global Positioning System devices (GPS) to test whether children were exposed to playground paintings at schoolyard or not. The interest of this device lies in being able to determine the real impact of the playground paintings (decrease of SB and increase in PA) on the real time

TABLE 2 | Average change in recess physical activity levels (% recess) across two follow-up measurements (6 and 12 months) from baseline in experimental group children compared to control group following a paintings playground intervention.

	%SED			%LPA			%MVPA		
	β (SE)	95%CI	*p*	β (SE)	95%CI	*P*	β (SE)	95%CI	*p*
Baseline PA	**0.23 (0.04)**	**0.15–0.31**	**<0.001**	**0.27 (0.04)**	**0.19–0.35**	**<0.001**	**0.35 (0.04)**	**0.27–0.43**	**<0.001**
Intervention (6 months)	–3.12 (1.64)	−6.33–0.09	0.06	**2.47 (0.93)**	**0.65–4.29**	**<0.001**	1.41 (1.13)	−0.80–3.62	0.21
Intervention (12 months)	−1.94 (1.71)	−5.29–1.41	0.26	−1.29 (0.98)	−3.21 to 0,63	0.19	**3.36 (1.18)**	**1.05–5.94**	**<0.001**
Sex (female)	**7.26 (0.88)**	**5.53–8.98**	**<0.001**	−0.34 (0.43)	−1.18 to 0.50	0.42	**–5.44 (0.66)**	**–6.73 to −4.14**	**<0.001**
Age	−0.02 (0.02)	−0.06–0.02	0.39	0.003 (0.01)	−0.02–0.02	0.84	0.02 (0.02)	−0.02–0.06	0.74
BMI group (overweight)	−0.53 (0.99)	−2.47–1.41	0.59	0.26 (0.54)	−1.32–1.32	0.63	0.24 (0.74)	−1.21–1.69	0.29
Time (6 months)	**4.12 (1.38)**	**1.41–6.82**	**<0.05**	0.28 (0.77)	−1.23–1.79	0.71	**–5.01 (0.97)**	**–6.91–3.01**	**<0.001**
Time (12 months)	**3.47 (1.44)**	**0.65–6.29**	**<0.05**	**2.55 (0.81)**	**0.96–4.14**	**<0.01**	**–6.59 (1.01)**	**–4.61–3.01**	**<0.001**

For intervention, time, sex, and Body Mass Index (BMI) group, control group, 1 month, boys and normal weight children are the reference groups, respectively. A positive β value indicates a positive intervention on physical activity (PA) levels of the experimental group compared with the control group during recess over time. The intervention β value represents the difference in physical activity levels for the experimental group against the control group when time, sex, age, BMI group are included in the final model. Bold value represent a significant value.

of exposure and not on the time of the recess. If the goal of this type of intervention was to increase physical activity and to tackle playground issues, GPS could be used in recess studies to determine how changing the playground environment influences activity and playground issues.

CONCLUSION

This study demonstrates that a playground markings intervention had a positive effect on MVPA when assessed using accelerometry. However, this intervention did not result in 12-months changes in SED and LPA. There is a need for further studies to consider the real exposure in this environment on children's physical activity levels in combining observation or GPS and accelerometry.

AUTHOR CONTRIBUTIONS

GB was involved in acquisition, analysis and interpretation of data, drafting, and manuscript writing. JA was involved in analysis and interpretation of data, drafting, and critically revising the manuscript. SB and FXG were involved in the conception and design of the paper and played a role in critically revising and editing the manuscript. All authors read and approved the final manuscript.

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Physical Activity, Inactivity, and Sedentary Behaviors: Definitions and Implications in Occupational Health

David Thivel[1,2]*, *Angelo Tremblay*[3,4], *Pauline M. Genin*[1,2,5,6], *Shirin Panahi*[3,4], *Daniel Rivière*[7] and *Martine Duclos*[2,5,6,8]

[1] Clermont Auvergne University, EA 3533, Laboratory of the Metabolic Adaptations to Exercise under Physiological and Pathological Conditions, Clermont-Ferrand, France, [2] CRNH-Auvergne, Clermont-Ferrand, France, [3] Département de L'éducation Physique, Faculté des Sciences de L'éducation, Université Laval, Québec City, QC, Canada, [4] Département de Kinésiologie, Université Laval, Québec City, QC, Canada, [5] INRA, UMR 1019, Clermont-Ferrand, France, [6] University Clermont 1, UFR Medicine, Clermont-Ferrand, France, [7] Département de Médecine Générale, Université Toulouse III, Toulouse, France, [8] Department of Sport Medicine and Functional Explorations, Clermont-Ferrand University Hospital, G. Montpied Hospital, Clermont-Ferrand, France

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Edited by:
Daniel P. Bailey, University of Bedfordshire Bedford, United Kingdom

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Joshua Z. Willey, Columbia University, United States
Hollie Raynor, University of Tennessee, United States

***Correspondence:**
David Thivel
david.thivel@uca.fr

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Based on the increasing evidence linking excessive sedentary behaviors and adverse health outcomes, public health strategies have been developed and constantly improved to reduce sedentary behaviors and increase physical activity levels at all ages. Although the body of literature in this field has grown, confusion still exists regarding the correct definition for sedentary behaviors. Thus, there is a need to provide a clear definition in order to distinguish sedentary behaviors from physical activity and inactivity. This paper will briefly review the most recent and accepted definitions of these concepts and illustrate their relationships. Nowadays, since most working adults spend a high proportion of their waking hours in increasingly sedentary tasks, there will be a particular focus on the field of occupational health. Finally, simple modifications in the workplace will be suggested in order to decrease sedentary behaviors.

Keywords: physical activity, sedentary behaviors, occupational health, inactivity, tertiary employees

INTRODUCTION

The beneficial effects of physical activity have been clearly described in the literature with recent meta-analyses providing a high level of evidence regarding its impact on overall mortality (1, 2), cardiovascular disease-related mortality (3), or cancer-relate mortality (3–5). In addition to reducing the risk of mortality, regular physical activity favors healthy growth and aging and prevents the occurrence of many chronic diseases (6). The last century has been the cradle of our societies' modernization and automation favoring the occurrence and development of sedentary opportunities and behaviors. This sedentariness has lately been described as a major mortality risk factor (7), independent of physical activity (8), and ∼5.3 million of deaths are attributed to physical inactivity (9).

A worker's activity has evolved throughout the last century, clearly shifting to more sedentary occupational tasks, and this "tertiarization" results in workplaces that are of particular concern. In their research, Church and colleagues reported a decrease of about 100 calories in the daily occupation-related energy expenditure over the last 50 years in the United States, which plays a significant role in the body weight of both men and women (10). To date, while few data are available regarding employees' physical activity, their sedentary time and health-related consequences have been particularly studied. Recent research including meta-analyses have clearly underlined the negative impact of seated occupational activities on overall mortality (11, 12). According to some studies, the mortality rate is increased by 2% for every seated hour and can reach up to 8% per hour when the total consecutive time spent seated is above 8 h per day (13). These statistics are part of a large body of evidence associating occupational activities with health issues, clearly urging for appropriate worksite interventions to improve tertiary employees' health.

Our societal changes, favoring the minimization of physical effort, are particularly problematic based on the assumption that individuals possess an innate tendency to conserve energy and avoid unnecessary physical exertion. This general trend to avoid energy expenditure may explain why people do not exercise regularly despite the known negative effects of physical inactivity on health (14–16). Moreover, we are currently living in a paradoxical time where our society has become more "technophilic," favoring strategies to avoid and/or minimize physical effort (and *per se* human motion) with more time devoted to sedentary behaviors; while on the other hand, there is a growing interest and concern for healthy lifestyles. Interestingly, new pharmacologic drugs for treating non-communicable chronic diseases are being sold with the message to move more and decrease the time spent sedentary, emphasizing the importance of an active lifestyle that cannot be replaced by any pharmacologic strategies. Both recommendations and public health strategies that promote physical activity and discourage sedentariness must rest on clear and universal definitions of these concepts to avoid any equivocal and misinterpreted messages.

The aim of this brief review is to (a) provide an update on the definitions of physical activity, inactivity and sedentariness; (b) examine their roles in occupational health; and (c) suggest simple modifications in the workplace in order to decrease sedentary behaviors.

DEFINITIONS OF PHYSICAL ACTIVITY AND SEDENTARY BEHAVIORS

Trained, active, inactive, and sedentary are some of the terms that have been used to describe many individuals. Misuse of these adjectives by public health communications, commercial advertisements, and scientific reports often leads to biased messages and conclusions.

For the last couple of years, researchers in the fields of physical activity and sedentary behaviors, particularly members of the Sedentary Behavior Research Network (SBRN), have worked together to clarify the definitions related to physical activity, inactivity and sedentary behaviors (**Table 1** presents the main definitions) (18). In 2017, a new terminology consensus was created to highlight the differences between these concepts [see Tremblay et al. (18)]. Physical activity is defined as any body movement generated by the contraction of skeletal muscles that raises energy expenditure above resting metabolic rate, and is characterized by its modality, frequency, intensity, duration, and context of practice. In 1985, Caspersen defined exercise as a subcategory of physical activity that is planned, structured, repetitive, and that favors physical fitness maintenance or development (17). Each word in this definition of physical activity is of crucial importance to properly understand its meaning. According to the last updated definition, while resting energy expenditure corresponds to an energy expenditure of one metabolic equivalent (MET), sedentary behaviors are any waking behaviors characterized by an energy expenditure ≤1.5 METs, while in a sitting, reclining, or lying posture (18). This last definition is of particular importance since in 2015 Gibbs and colleagues called for a better definition of sedentary behaviors that considers both intensity and posture (19). Screen time and sitting time are usually the two main indicators used to quantify the time devoted to sedentary behaviors. From an energetic and biological point of view, there is also a clear need to consider the exact nature of each sedentary behavior that may not have similar physiological consequences. Indeed, sedentary activities demanding cognitive effort favor an increase in cortisol concentrations, glycemic instability, energy intake as well as a decrease in the parasympathetic/sympathetic balance (20). Such physiological implications have to be considered since sedentary behaviors involving cognitive tasks (mental work) have the profile of an activity with very low movement and with a component of neurogenic stress (20–22).

TABLE 1 | Main definitions.

Terms	Definitions
Physical activity	Any body movement generated by the contraction of skeletal muscles that raises energy expenditure above resting metabolic rate. It is characterized by its modality, frequency, intensity, duration, and context of practice (17)
Physical inactivity	Represents the non-achievement of physical activity guidelines
Exercise	Subcategory of physical activity that is planned, structured, repetitive, and that favors physical fitness maintenance or development (17)
Sport	Sport is part of the physical activity spectrum and corresponds to any institutionalized and organized practice, reined over specific rules
Sedentary behaviors	Any waking behaviors characterized by an energy expenditure ≤1.5 METs, while in a sitting, reclining, or lying posture (18)

Physical activity and sedentary behaviors are not the opposite of each other. Individuals are considered to be active when they reach physical activity recommendations for their age, which does not prevent them from also devoting a significant part of their time to sedentary behaviors. In other words, individuals can be classified as both active and sedentary. Tertiary employees are the most demonstrative example of sedentariness as they spend a considerable part of their time seated in front of a computer screen. This defines them as highly sedentary, while they may or may not reach their aged-related physical activity recommendations outside of work (23). This confusion mainly rests on the challenge of differentiating between sedentariness and physical inactivity that must be defined as not following physical activity guidelines. This inappropriate understanding of these terms can be illustrated using the recent paper by Rantalainen et al. (24), who compared the amount and patterns of time devoted to moderate-to-vigorous physical activities (MVPA) between two groups of habitual recreational runners: (i) running between of 20 to 40 km per week and (ii) running more than 50 km per week) and a "sedentary group" composed of office workers (24). However, to be included in their "sedentary group," participants had to engage in <150 min per week of MVPA, defining them as inactive and not sedentary. The misuse of the concept in this study was justified by the fact that the three groups showed a statistically similar overall sedentary time. This study clearly highlights that individuals may be classified as both active and sedentary and that inactive and sedentary must not be confused in order to avoid any misinterpretations, incorrect conclusions and/or public health messages (25).

Similarly, the term physical activity is commonly confused with sport (not at the scientific level). Sport is part of the physical activity spectrum and corresponds to any institutionalized and organized practice, based on specific rules. Some very active individuals might not be sport athletes even though they regularly train and show a high level of physical activity. This distinction is of importance with respect to public health messages since individuals and patients may fear the term "sport" while what is really required is a higher or regular amount of physical activity participation.

Once clearly understood, the adoption of these different concepts rests on individuals' behaviors. It is important to consider the behavioral dimensions of physical activity and sedentariness. To be physically active and avoid too much sedentary time is, today, a voluntary behavior. External and societal influences are strong, but these constraints must be changed into habits. Physical activity must be included as a core element of human nature and we must go back from what Epstein referred to in the nineties as "sedentary alternatives" (26) to daily "active alternatives" (27).

SEDENTARY BEHAVIORS AND PHYSICAL ACTIVITY: IMPLICATIONS IN OCCUPATIONAL HEALTH

While the worksite has been recently suggested as a new strategic opportunity to promote physical activity, due to the important amount of time employees spend at work, the "tertiarization" of work also highlights the urgent need to fight sedentary behaviors and sedentary time during working hours. The prevalence of sedentary professions increased by 20% in the United States between 1960 and 2008, with a concomitant decline of more "physically active professions" (10). In France, working adults have been shown to spend about 10 h per day sitting on workdays (with at least 4.17 h/day seated at work) and 7.58 h/day sitting on non-workdays, with a clear association between the time spent sedentary at work and sedentary behaviors outside of work (28). These data underline that physical activity programs and interventions must be proposed to tertiary employees to increase their activity levels. Strategies that aim at breaking this sedentary time must also be conducted. Recent data have shown that among office workers, who spend at least 7 h per day seated at their desk mostly in front of a screen, health indicators such as waist circumference, body mass index, or fat mass are not improved among active employees compared to inactive ones, suggesting the potential negative impact of sedentary time over physical activity levels (29). These results are of particular importance and are associated with recommendations formulated by Rosenberg et al. calling for interventions targeting high-risk populations, such as tertiary employees (30).

Standing work stations have been proposed to break this sedentary time. Although standing stations remain inactive, according to the framework proposed by the Sedentary Behavior Research Group, passive standing corresponds to 2 METs, which is above the 1.5 METs threshold used to define sedentary behaviors, considered as low physical activity (18). Although this energetic cost of passive standing rests on a strong body of scientific evidence, a recent study showed that passive standing does not significantly increase heart rate and energy expenditure above rest (31). According to the authors, the observed rises in heart rate and energy expenditure are due to the transition from sitting to standing before returning to resting values, particularly in "energy saver individuals" (31). This may explain why some studies failed to find any effects of standing desk allocation vs. classical sitting on metabolic profiles and body composition among tertiary employees (32). This could also explain why regular sitting breaks have been shown to improve health compared with permanent passive standing positions (33). In their research, Bailey and Locke showed that only active breaks consisting in brief bouts of light-intensity activities (2-min walk every 20 min) but not passive standing breaks might enhance cardiometabolic health in tertiary employees (34). Although further research is needed regarding the exact effects of standing desks and regular breaks, active standing (18) such as walking and cycling desks or walking breaks should be prescribed, regardless of the employees' physical activity level. Even though new investigations are warranted, some promising results already demonstrate the beneficial effect of walking or bike-desks on overall health, well-being, and work-related cognitive performance among tertiary workers (35). Some recent findings have also underlined the cardiometabolic benefits obtained by interrupting sitting time by the use of active walking desks compared with prolonged sitting (36). Future research should consider a potential inter-individual variability in the responses to such strategies, with some people that might adopt compensatory mechanisms leading to increased sedentary time outside of work, for instance.

While worksites have been pointed out as new ideal settings to promote physical activity, the complexity of tertiary activities that by definition favor sedentariness, combined with the independent effect of sedentary time and physical activity on health, must lead stakeholders and practitioners to conduct individualized interventions not only favoring physical activity but also, breaking this sedentary time. Even though it has been suggested that performing 60–70 min of moderate physical activity per day could eliminate the deleterious impact of sitting time, it does not eliminate the increased risk associated with screen time (37). Moreover, only a small proportion of the population reaches such an amount of daily physical activity, which must reinforce individualized strategies. It is important to note that breaking apart sedentary times and having little bouts of light physical activity is the beginning of human mobility for our tertiary physically inactive and sedentary bodies, whose genes were programmed 40,000 years ago to walk not only 30 min a day (2.5 km) but 20 km per day (38).

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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Worksite Physical Activity Barriers and Facilitators: A Qualitative Study Based on the Transtheoretical Model of Change

*Jo-Hanna Planchard, Karine Corrion, Lisa Lehmann and Fabienne d'Arripe-Longueville**

Université Côte d'Azur, LAMHESS, Nice, France

Background: Many of the studies on worksite physical activity (PA) have investigated either the effectiveness of PA programs for employees and the work-related outcomes or health promotion interventions to increase PA. However, studies on barriers and enabling factors for participation are scarce and have generally not been theoretically grounded. The purpose of this qualitative study was to identify worksite PA barriers and facilitators from the perspective of the transtheoretical model of change (TTM).

Methods: Thirty employees (15 females and 15 males; $M_{age} = 44.70$; $SD = 5.20$) were recruited to participate in semi-structured interviews lasting from 60 to 90 min. Participants came from several organizations that offered PA programs and were at different exercise stages of change. They were invited to describe: (a) general information on the place of PA in their daily lives and in the workplace, and the reasons for (b) worksite PA participation or (c) non-participation. The interview transcripts were analyzed both inductively and deductively with reference to the exercise stages of change.

Results: Three categories of barriers and facilitators related to physical, psychological and environmental dimensions were identified. For all exercise stages of change combined, psychological and environmental barriers were significantly more reported than physical barriers, whereas physical and psychological facilitators were more cited than environmental facilitators. Further qualitative analysis suggested that these categories differed with the exercise stage of change. At the precontemplative and contemplative stages, all types of barriers predominated (e.g., physical constraints due to the workstation, fear of management disapproval, time constraints). At the preparation stage, physical, and psychological needs emerged in relation to worksite PA (e.g., need to compensate for sedentary work, stress regulation). At the action and maintenance levels, physical, psychological, and environmental facilitators were reported (e.g., enhanced physical condition, workplace well-being, social ties). At the relapse stage, specific life changes or events broke the physically active lifestyle dynamics.

Conclusion: This study identified the contribution of different types of worksite PA barriers and facilitators according to the exercise stage of change. The identified facilitators are consistent with the general TTM processes of change, while being specific to the workplace. Practical strategies are discussed.

Keywords: physical activity, workplace, transtheoretical model, behavior change, stage of change

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Siti Munira Yasin, Universiti Teknologi MARA, Malaysia

****Correspondence:***
Fabienne d'Arripe-Longueville
longuevi@cotedazur.fr

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INTRODUCTION

The international community (1) has recognized the workplace as a suitable site for health promotion and raising awareness of the risk factors for obesity, diabetes, and cardiovascular disease. Physical activity (PA) programs to improve employee health have been implemented in many organizations, and research on this subject has correspondingly intensified. Three main categories of studies can be identified in the literature. The first category pertains to the types of worksite PA interventions that have been implemented. A recent systematic meta-review by Jirathananuwat and Pongpirul (2) classified and described interventions to promote workplace PA based on the evidence from systematic reviews and meta-analyses. Using the PRECEDE-PROCEED model, the interventions were classified into predisposing, enabling, reinforcing, environment, and policy domains of focus. Of the 48 interventions identified, 22 (46%) focused on predisposing employees to have more PA (information delivery and training programs) and 17 (35%) focused on enabling them to do so (instrument resources and health service facilities). The reinforcing approaches included incentives and social support, whereas the remaining interventions targeted environmental development and policy regulation.

The second category of studies examines the effects of PA programs and has revealed quite inconsistent findings to date. The meta-analysis by Conn et al. (3) indicated that workplace PA interventions can improve employee health (i.e., PA behavior, fitness, lipids, anthropometric measures, and job stress). More recent studies have also suggested that workplace interventions that are compatible with productive work (i.e., alternative workstations, interventions promoting stair use, and personalized behavioral interventions) reduce sedentarity and increase PA behaviors at work, with some of the interventions (i.e., multi-component and environmental strategies) positively influencing these behaviors in all aspects of daily life (4, 5). Nevertheless, the evidence has been inconsistent regarding the impact of these programs on employee productivity, including measures like absenteeism, employee turnover, and job satisfaction (6, 7), and the cost-effectiveness for employers (8). In addition, the long-term effects of PA interventions remain to be established.

The third category of research examines the factors that determine participation in workplace PA programs. A few qualitative studies have explored perceived barriers and/or facilitators of workplace PA using individual semi-structured interviews (9, 10) and focus groups (11). The results have consistently shown that the main barriers are physical limitations due to pain and weakness, lack of motivation, lack of time, and work commitment, whereas the strongest motivators are family relationships, social support and perceived health benefits (e.g., better health management). Other studies have pointed out that the barriers emerge from an interaction between management, employees, and intervention characteristics, thus emphasizing the importance of organizational support strategies (12–14). The quantitative studies have demonstrated that sociodemographic factors like gender and the type of intervention (i.e., multi-behavior) are significant factors of participation (15). For example, Beck et al. (16) reported that white, female, non-union staff and employees seeking preventive care were the most likely to participate in preventive programs. A few studies have examined the barriers and motivators of worksite PA from the perspective of sociocognitive models. Keller et al. (17) reported an increase in self-efficacy, planning and PA following a workplace intervention and showed that planning was consistently associated with subsequent PA. Hadgraft et al. (18) suggested that strategies aimed at increasing employees' perceived control and self-efficacy over their sitting time might be helpful components of workplace interventions, although they only partially explained the variation in reduced workplace sitting.

Deeper insight into the perceived barriers and facilitators of worksite PA is needed at this point and this might be best accomplished through studies based on theoretical models of behavior change. An important factor that can explain individual variability among employees is the exercise stage of change. The transtheoretical model (TTM), which deals with behavior change through a temporal dimension of readiness to change (19), has been applied to several health behaviors, and it was also found useful for understanding the mechanisms by which people become physically active (20, 21). PA behavior change occurs through a series of five stages (22, 23): (a) precontemplation (i.e., no intention of becoming physically active and awareness of the problems associated with this behavior), (b) contemplation (i.e., awareness of the negative effects of inactivity with intention to start practicing PA), (c) preparation (i.e., making small changes in behavior—joining a gym, for example—but still not meeting a criterion for physical activity), (d) action (i.e., meeting a criterion of physical activity, but only recently—usually within the past 6 months), and (e) maintenance (i.e., meeting a criterion for physical activity for 6 months or longer).

Decisional balance, which can be defined as a balance in the perceived advantages and disadvantages of change, is one of the factors hypothesized to mediate the change process. The perception of the advantages associated with PA (i.e., facilitators) is strong in the last two stages (i.e., action and maintenance), whereas the perception of the disadvantages (i.e., barriers) is strong in the early stages (i.e., precontemplation and contemplation) (24). Preparation is the stage at which the potential gains are in balance with the perceived losses. Stage progression follows a somewhat cyclical pattern, with individuals progressing and regressing through the stages. The perceived barriers and facilitators are important for predicting the transitions between precontemplation, contemplation, and preparation, but less so for action and maintenance (21).

Many worksite PA studies have focused on the types and effectiveness of PA programs for employees and the work-related outcomes. Research on the barriers and enabling factors of participation is scarce, however, and in general has not been theoretically grounded. It seems likely that the TTM would help capture the PA stages of change of employees, but it has never been applied to worksite PA. The purpose of this qualitative study was thus to provide a comprehensive understanding of worksite PA barriers and facilitators from the perspective of the Transtheoretical Model of change (TTM).

METHODOLOGY

Study Design and Setting

This study used qualitative methods involving individual interviews. The interview guide was developed on the basis of the literature on health (24), worksite (15), and exercise psychology (25). The research team was familiar with this literature and qualitative methods. The interviews were semi-directive, with semi-structured questions (26, 27). The procedure had three phases. First, following authorization from the different organizations, an initial visit was arranged to explain the nature and goal of the investigation and distribute consent forms. Signed informed consent was obtained prior to conducting the interviews. Second, the first author conducted a pilot interview with two employees (one male and one female). These interviews helped to adjust the interview guide and ensure the flow of the interviews, respecting the principles of sympathetic understanding (28) and neutrality (27). Third, the individual semi-structured interviews were conducted and lasted an average of 40 min. Each interview was recorded in a private room with no distractions. Written notes were used to facilitate follow-up questions. Confidentiality was ensured and the following coding system was adopted: T1 to T30. Once transcribed, the verbatim interviews were given to the participants so that they could check the content and quality of the transcript. This entailed a few minor changes.

During the interviews, the participants were invited to provide information about: (a) PA practice in their daily lives and (b) the reasons for worksite PA participation or (c) the reasons for worksite PA non-participation. The first part included general information on the types, forms and locations of PA in the employees' daily lives (e.g., *What type of PA do you do in your free time?*). The second part aimed to identify the perceived barriers (arguments against) and facilitators (arguments for) of PA practice in daily life (e.g., *What elements contribute to your regular PA practice?*). The third part was devoted to the perceptions of the barriers and facilitators of workplace PA practice [e.g., *What are the reasons for practicing (or not practicing) physical activity in the workplace?*]. Finally, in part three, questions about the worksite PA offer were raised: *What do you think about the PA offer that is available? What are the advantages or disadvantages of this offer?*

Study Sample

Thirty French employees (15 females and 15 males; $M_{age} = 44.70$; $SD = 5.20$) were recruited. In order to have a variety of workplace profiles, participants were recruited in public or private organizations offering PA programs: (a) 10 employees from a public university, (b) 10 employees from a hospital, and (c) 10 employees from private companies (see **Table 1**). They were predominantly white and educated. All the participants were at different exercise stages of change (29). All gave signed informed consent before engaging in the study.

TABLE 1 | Socio-demographic and workplace characteristics among participants ($n = 30$).

Variables	Number
GENDER	
Women	15
Men	15
AGE (YEARS)	
20–40	13
40–60	17
JOB CHARACTERISTICS	
Administrative staff	11
Doctors/Nurses/Professors/Teachers/Engineers	10
Lab technicians/workers/Assistants	9
EDUCATION	
Elementary school	0
Middle school	2
High school	10
College	18
MARITAL STATUS	
Single	4
Married or living with someone	15
Separated or divorced	9
Widower	2
STAGE OF CHANGE	
Precontemplation/contemplation	8
Preparation	6
Action/maintenance	11
Relapse	5

Data Analysis

The interviews were transcribed *verbatim*. The interviews were stopped when saturation was reached, which was the point at which no new themes or information emerged (30). To ensure that the determined codes and categories were embodied in rather than forced on the data (31), we adopted both inductive and deductive content analyses for the interview transcripts (32). Deductive content analysis was based on the categories (physical, psychological, and environmental) of barriers and facilitators in relation to the exercise stages of change. Two researchers (the first and last authors) independently coded the transcripts. They identified and grouped meaning units (MUs) into subcategories within the main categories. The researchers discussed the categorization until consensus was reached. Then, two other researchers, the second and third authors, considered as disinterested peers (i.e., blind to the analysis and purpose of the study), were invited to verify the encodings and interpretations of the data (30). Their analyses were up to 92% in agreement with those of the first two researchers, which is considered high (33, 34). Last, a binomial exact test was used to compare a proportion with an expected value, all exercise stages of change combined. Results were considered significant at $p < 0.05$.

RESULTS

All the transcribed interviews were analyzed line by line and this content analysis identified 623 MUs related to the study purpose:

272 MUs were related to the perceived barriers to workplace PA and 351 MUs were related to the perceived facilitators.

Perceived Barriers and Facilitators of Worksite PA

Three categories of barriers and facilitators related to the physical, psychological and environmental dimensions were identified (see **Table 2**). The binomial exact test analysis revealed that the employees cited psychological or environmental barriers significantly more often than physical ones (Binomial = 0.022, $p = 0.5$), but reported physical or psychological facilitators significantly more often than environmental ones (Binomial = 0.001, $p = 0.5$). Of the perceived physical facilitators of PA practice in the workplace, 86% of the employees reported improved fitness. The most often mentioned psychological benefit was awareness of the positive effects of PA on health, reported by 76%. For the environmental facilitators, 53% of the participants mentioned time savings. The most often mentioned physical barrier was the physical constraints specific to the job position (53%), thus limiting the employee's commitment to PA in the workplace. The low acceptability of PA in the organization's norms was the most frequently mentioned psychological barrier, noted by 60% of the employees. For the environmental barriers, inadequate program supervision was noted by 56%.

Worksite Physical Activity Barriers and Facilitators According to the Participants' Stage of Change

The perceptions of barriers and facilitators changed over the course of the stages of change (i.e., precontemplation and contemplation, preparation, action/maintenance, and relapse). The results are shown in **Table 3**.

Precontemplative and Contemplative Stages

The employees in these stages were physically inactive and had little interest in PA in general and at the workplace in particular. They mostly mentioned barriers to practice compared to facilitators.

Physical domain

The main physical barriers were: (a) the physical constraints of the job, (b) personal physical limitations, and (c) job restrictions. The physical constraints were characterized by the activities inherent to the job, as illustrated in this excerpt: "*I help patients to get up and wash every day – I already do PA at work*" (M25). PA was also seen as potentially causing physical limitations, such as fatigue or pain, as noted in the following excerpt: "*I'm tired enough with my daily work, so I'm not going to tire myself out any further*" (M12).

TABLE 2 | Perceived barriers to and facilitators of worksite PA practice at workplace.

	Types	Number of MUs	Number of employees	Characteristics of barriers and facilitators
	Physical	230 MUs (65.5%)	26 21 12 9	– Improved physical fitness – Weight loss – Disease prevention – Improved sleep
Perceived facilitators of PA practice at the workplace (351 MUs; 56.3%)	Psychological	90 MUs (25.7%)	24 12 10 7 6	– Awareness of positive effects of PA on health – Improved cognitive efficiency at work – Improved social self-esteem at work – Improved social ties in the organization – Improved psychological well-being and less work stress
	Environmental	31 MUs (8.8%)	16 8	– Time savings (remain onsite) – Financial advantages
	Physical	82 MUs (30%)	16 5 4	– Physical constraints of workstation – Physical restrictions of workstation – Physical limitations (fatigue, pain due to exercise)
Perceived barriers to PA practice at the workplace (272 MUs; 43.7%)	Psychological	83 MUs (30%)	18 12 8 7	– Perceived low acceptance of PA according to organization norms – Fear of reduced productivity – Fear of management disapproval – Fear of physical discomfort (sweating)
	Environmental	107 MUs (40%)	17 11 9 8	– Inadequate offer of PA – Inadequate equipment available – Inconvenient hours – No showers or changing rooms

N = 30; MUs, Meaning Unit.

TABLE 3 | Worksite physical activity barriers and facilitators according to the participants' stage of change.

Stage of change	Physical domain		Psychological domain		Environmental domain	
	Barriers	**Facilitators**	**Barriers**	**Facilitators**	**Barriers**	**Facilitators**
PC/C ($n = 8$)	– Physical constraints linked to job position ($n = 5$) – Physical limitations (fatigue, pain) ($n = 4$) – Restrictions of job position ($n = 2$)		– Fear of management disapproval ($n = 3$) – PA not a priority for the employee ($n = 2$)	– Awareness of positive effects of PA for health ($n = 8$)	– Work overload /not enough time ($n = 6$) – Inconvenient PA hours ($n = 4$)	
PR ($n = 6$)	– Physical limitations (fatigue, pain) ($n = 4$)	– Need to physically compensate for sedentary work ($n = 5$) – Need to lose weight ($n = 4$) – Need to have a healthier lifestyle ($n = 2$)	– Fear of lower productivity ($n = 4$) – Fear of physical discomfort (effort; muscle aches; sweating) ($n = 2$)	– Need to handle work-related stress ($n = 4$) – Awareness of PA benefits for health ($n = 3$) – Perception of management approval ($n = 2$) – Motivational contagion between employees ($n = 2$)	– Work overload/not enough time ($n = 3$) – Inadequate program and/or framework proposed ($n = 2$) – Poorly adapted equipment made available ($n = 2$) – No showers or changing rooms available ($n = 1$)	– Time savings (remain onsite) ($n = 4$) – Financial advantage ($n= 3$)
A/M ($n = 11$)		– Improved physical fitness ($n = 10$) – Weight loss ($n = 8$) – Improved sleep ($n = 5$) – Healthier lifestyle (eating better; stopped smoking) ($n = 2$)		– Reduced work-related stress ($n = 7$) – Improved psychological well-being ($n = 6$) – Improved social self-esteem at work ($n = 5$) – Improved cognitive efficiency on the job ($n = 3$) – Improved social ties in the organization ($n = 2$) – Management approval ($n = 2$)	– Work overload / not enough time ($n = 4$)	– Time savings (remain onsite) ($n = 8$) – Financial advantage ($n = 7$)
R ($n = 5$)	– PA-related injury ($n = 2$) – Work accident ($n = 1$) – Sick leave ($n = 1$)		– Major conflict with a manager or colleague ($n = 3$)		– PA hours changed ($n = 2$) – Program or framework changed ($n = 2$) – New family constraints ($n = 1$)	

PC/C, Precontemplation/Contemplation stages; PR, Preparation stages; A/M, Action/Maintenance stage; R, Relapse.

Psychological domain

Although all participants were aware of the health benefits of PA, several barriers could be identified at the psychological level. First, the employees were sensitive to the degree of PA acceptability within their organization and feared the disapproval of management, as expressed by these participants: "*The employer* *takes a dim view of PA*" (M4) with PA being seen as synonymous with "*leisure time and amusement*" (F8). In addition, many expressed the conviction that workplace PA was not a priority and for a variety of reasons. Some believed that work was not the right place for PA and they preferred to keep their autonomy for this practice "*out of respect for my private life*" (F11) and "*not [to] be seen by the other employees*" (M15); others thought it would hinder their productivity, as evidenced by this excerpt: "*Right now I have other priorities at work; I have objectives I want to reach*" (M9).

Environmental domain

Environmental barriers were mentioned such as a heavy workload and time constraints.

Preparation Stage

In the preparation stage, the employees were preparing for change, making the actual decision to do so. They expressed a balance between perceived barriers and facilitators.

Physical domain

Although limitations were still mentioned (e.g., fatigue, musculoskeletal disorders, joint pain), several facilitators were identified: (a) the need to physically compensate for a sedentary job, (b) the need to lose weight, and (c) the need to improve one's lifestyle, as respectively illustrated in the following excerpts: "*I sit in front of my screen for 8 hours a day; I feel a need to move, to do something athletic*" (M12). "*Since I've been working here, I've gained 20 pounds and my doctor told me to lose weight to protect my knees and back*" (M6).

Psychological domain

Several barriers were still mentioned, such as the fear of being unproductive on the job and the fear of physical discomfort, notably muscle aches and sweating. On the other hand, several types of psychological facilitators were noted in addition to the awareness of the perceived health benefits of PA mentioned in the earlier stages. The main facilitator was the possibility of managing the work stress generated by aggressiveness both within and outside of the organization, as illustrated by the following excerpts: "*When I'm involved in a physical activity, I feel less stressed out*" (M7). "*PA helps me to react better to the aggressiveness of patients and their families*" (F1). Many of the participants said that management's approval of this practice was very important, as illustrated by this excerpt: "*If this proposal is supported by top management, I'd be interested in trying it*" (F3). Last, motivational contagion from the group involved in the PA program was mentioned by many as a facilitating factor in deciding to begin workplace PA (e.g., positive group dynamics, social ties, conviviality): "*Doing this with my work colleagues is fun and makes me want to continue*" (M10).

Environmental domain

In addition to the workload and lack of time expressed in previous stages, the following environmental barriers were mentioned: (a) an inadequate program and/or framework, (b) inadequate equipment, and (c) no accessibility to showers and/or changing rooms. These excerpts illustrate some of these barriers: "*We would like to have a personalized coach*" (M14). "*There are no showers or changing rooms at the workplace*" (F2). Two categories of environmental facilitators were identified: (a) time savings and (b) financial benefits, as expressed by this employee: "*It's not expensive compared to a club*" (M27).

Action and Maintenance Stages

In these stages, the change was real and observable. Barriers were no longer brought up and the employees spoke only of the facilitators, even though perceptions of a work overload and a lack of time persisted.

Physical domain

The main physical facilitators were the improvement in overall fitness and weight loss, as these remarks show: "*Before, I got breathless when I took the stairs; since I've been practicing PA, I feel the difference*" (F25). "*Since I started PA, I've lost weight and I feel better*" (F24). "*I sleep better at night and I now have a healthy lifestyle*" (M7).

Psychological domain

Six types of psychological facilitators were identified: (a) reduced work stress ("*I'm working in better conditions and I feel more relaxed since I started,*" M22), (b) improved psychological well-being, (c) improved social self-esteem at work ("*PA practice improves the image I have in my work compared to inactive colleagues,*" M26)., (d) improved cognitive efficiency ("*We're more efficient at work since we started PA,*" F28)., (e) improved social ties within the organization ("*It's a nice moment for coming together and sharing*" (F11) with "*a really positive group dynamic,*" M1)., and (f) the approval of management ("*There is a real corporate culture around sport. We feel that it is supported and approved of. So it encourages us to participate without guilt!*" F3).

Relapse Stage

In the relapse stage, the employees cited only barriers.

Physical domain

Three physical barriers were identified that could occur at any time: (a) injury during PA practice, (b) a work accident, and (c) a sick leave. The following excerpt illustrates this type of physical barrier to practice: "*I've had to stop my physical activity since my work accident*" (M24).

Psychological domain

A conflict with a supervisor or colleague was a psychological barrier to PA practice, as this quote indicates: "*I don't participate anymore because I don't want to run into this colleague at the PA sessions*" (F15).

Environmental domain

Last, environmental changes could be barriers to daily practice at this stage, such as: (a) a change in session schedules, (b) a change in the framework and/or program, and (c) new family constraints.

DISCUSSION

The aim of the present study was to better understand the barriers to and facilitators of worksite PA from the perspective of the transtheoretical model of behavior change. The analysis of the qualitative data collected during the semi-structured interviews identified three categories of barriers and facilitators related to the physical, psychological and environmental domains, and the repartition differed with the participants' exercise stages of change.

An important finding is that the PA barriers and facilitators that emerged were multidimensional and shared similarities with those of other contexts and populations, while also showing specific workplace-related characteristics. The most frequently mentioned barriers concerned the physical constraints related to the workstation, the low acceptability of PA in the organization's norms, the fear of lower productivity, and the inadequacy of the equipment or supervision. The main identified facilitators were improved physical fitness and weight loss (physical dimension); awareness of the positive effects of PA on health, improved cognitive effectiveness at work, and improved social self-esteem at work (psychological dimension); and time and money savings (environmental dimension). A part of these results is consistent with the barriers and facilitators previously identified in the general population or vulnerable populations. For instance, the barriers related to physical constraints such as fatigue or pain, or the inadequacy of equipment or supervision, appear as obstacles widely shared by the general population (35, 36) including employees (9), older people (37), and people with chronic diseases (38). In the same vein, facilitators such as improved physical fitness and weight loss (physical dimension), awareness of the PA benefits to health, and time and money savings appear as common enablers of PA in the literature (35, 39). However, factors such as the low acceptability of PA in the organization's norms (and therefore fear of management disapproval) and fear of lowered productivity appear as factors pertaining to professional activity and its context. From this point of view, our results provide support to previous work showing the role of organizational-support strategies (40). Similarly, improved cognitive effectiveness and social self-esteem at work appear as worksite-related facilitators of PA already outlined in the workplace literature (6).

One strength of this study is that it highlights the shifting distribution of these three categories of PA barriers and facilitators according to the employees' stages of change based on the TTM framework (22, 23). The precontemplative and contemplative stages were characterized by all types of PA barriers (e.g., physical constraints due to the job position; fear of management disapproval; lack of time), although awareness of PA benefits for health was observed for all participants. At the preparation stage, physical and psychological needs related to worksite PA (e.g., need to compensate for sedentary work, stress regulation, and time savings) emerged. At this stage, there was a balance between perceived PA facilitators (e.g., need to lose weight or improve one's lifestyle; motivational contagion between employees) and barriers (e.g., fear of lowered productivity or physical discomfort; inadequacy of the program, coaching, and/or equipment). At the action and maintenance levels, physical, psychological, and environmental facilitators were mainly reported (e.g., enhanced physical condition, workplace well-being, social ties at work) while the barriers were minor (e.g., workload). Finally, at the relapse stage, specific life changes or events (e.g., accident, conflict, or a change in schedules) could break the physically active lifestyle dynamics. These events were able to cause a relapse in employee behaviors and reverse the decisional balance toward perceived barriers. These results enrich the existing literature on physical activity at the workplace based on the TTM model (20, 29) by providing a qualitative understanding of the stages of change dynamics.

The strengths of this work, as with any study, should be considered in light of its limitations. First, the generalizability of our findings may be questioned given the limited sample size. Although we used purposive sampling to ensure a variety of workplaces and professional activities, additional interviews in other professional contexts would need to be conducted to enrich our results. Moreover, the participants were interviewed about a potentially sensitive topic and may have given socially desirable answers. To address this in future research, observational data could be added to assess the consistency of different data sources (41). Selection bias could also have resulted from a non-response. It may be that the employees who participated in this study were more engaged in addressing lifestyle issues than those who did not participate. Finally, due to the limited time of those who participated, it was difficult to conduct in-depth interviews of 60 min. Therefore, our interviews lasted an average of 40 min. Although we found a great variety of answers and saturation was reached or almost reached in the last interviews, more time might have favored the emergence of new subthemes.

The results of this study suggest several practical implications. First, managers and public health practitioners who want to promote PA in the workplace will have to take into account their employees' stages of change and the multidimensional nature of the barriers and facilitators allowing them to evolve. Second, our results suggest that promotion strategies will have to attempt to resolve some paradoxes. Although the employees appeared globally aware of the positive effects of PA for health, the workplace did not seem to be an adapted context for all of them. Specifically, the fear of lowered productivity might have prevented some of them from engaging in worksite PA, even though those who did so reported better cognitive efficiency at work after exercising. Furthermore, the major psychological barrier, which was the low acceptability of PA in the organization's norms, indicates the importance of ensuring that worksite PA becomes a strategic priority and that PA interventions are smoothly integrated into the organizational routines. Finally, the wide range of the employees' needs suggests that the PA offers should be as individualized as possible and particularly adapted to the constraints of workstations and motivational profiles.

CONCLUSION

This study offers an original qualitative insight into the multidimensionality of PA barriers to and facilitators of worksite PA. For all exercise stages of change combined, psychological and environmental barriers were significantly more reported than physical barriers, whereas physical and psychological facilitators were more cited than environmental facilitators. However, framing this study within the TTM allowed us to capture their dynamics according to the participants' exercise stages of change. Pursuit of such work should be beneficial to public health practitioners and organizations for the design of optimal PA strategies, which should offer PA programs and intervention contexts based on the barriers and facilitators characteristics of each exercise stage of change. Future research based on the TTM should specify the most favorable workplace interventions to help employees moving from one stage to another and should examine the effects of programs in light of these stages of changes along with motivational profiles and workstation constraints.

ETHICS STATEMENT

The protocol of this study was approved by the local committee of The Université Côte d'Azur.

AUTHOR CONTRIBUTIONS

J-HP oversaw collection of the data, contributed to the analysis and interpretation of the results, and drafted the results' section of the manuscript. KC contributed to the analysis and interpretation of the results, and contributed to the writing of the manuscript. LL contributed to the interpretation of the results and oversaw the writing of the manuscript. FdA-L was responsible for the scientific project and oversaw the collection and analysis of data, contributed to the interpretation of the results, and helped writing the manuscript. All authors have read and approved the final version of the manuscript and agree with the order of presentation of the authors.

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Using Point-of-Choice Prompts to Reduce Sedentary Behavior in Sit-Stand Workstation Users

Miranda L. Larouche[1], Sarah L. Mullane[1], Meynard John L. Toledo[1], Mark A. Pereira[2], Jennifer L. Huberty[1], Barbara E. Ainsworth[1] and Matthew P. Buman[1]*

[1] *College of Health Solutions, Arizona State University, Phoenix, AZ, United States,* [2] *Division of Epidemiology and Community Health, University of Minnesota, Minneapolis, MN, United States*

Introduction: Desk-based office workers are at occupational risk for poor health outcomes from excessive time spent sitting. Sit-stand workstations are used to mitigate sitting, but lack of workstation usage has been observed. Point-of-choice (PoC) prompts offer a complementary strategy for office workers to break up their sitting time.

Study purpose: The purpose of this study was to examine the preliminary efficacy, preference, and acceptability of a theory-driven (i.e., 40 unique prompts encompassing social cognitive theory; TD-PoC) and an atheoretical basic reminder PoC prompt intervention (R-PoC) on reducing sedentary behavior in office workers with self-reported low sit-stand workstation usage (≤4 h per day).

Methods: In a cross-over design, participants ($N = 19$, 78.9% female, 39.4 ± 10.7 years of age) completed a 5-days no-prompt control condition followed by a random and counterbalanced assignment to one of the TD-PoC and R-PoC active conditions with a 1-week washout period between. Preliminary efficacy was assessed during work hours with the activPAL micro accelerometer. Preference was assessed prior to each active condition and acceptability was assessed following each active condition via questionnaire.

Results: The R-PoC prompt condition significantly decreased sitting time (b[se] = −49.0 [20.8], $p = 0.03$) and increased standing time (b[se] = 49.8 [19.7], $p = 0.02$) and displayed a significant increase in sit-stand transitions (b[se] = 2.3 [1.1], $p = 0.04$), relative to no-prompt control. Both the R-PoC and TD-PoC prompt conditions significantly decreased time spent in prolonged sitting bouts at b[se] = −68.1 [27.8], ($p = 0.02$), (b[se] = −76.7 [27.1], $p = 0.008$) relative to no-prompt control. Overall, the TD-PoC prompt condition displayed higher preference and acceptability ratings; however, these differences were not significant (p's > 0.05).

Conclusion: While the R-PoC prompt condition was slightly more efficacious than the TD-PoC prompt condition, the TD-PoC prompt condition was rated with higher preference and acceptability scores. Large variations between participants in preference, acceptability, and intervention feedback may indicate need for tailored messaging which may facilitate sustained use in the long-term.

Keywords: office workers, sedentary behavior, intervention, preference, acceptability, efficacy

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****Correspondence:***
Miranda L. Larouche
mlarouch@asu.edu

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INTRODUCTION

Desk-based occupations confine office workers to a seated position during the working day (1) of which 70–80% of work time is spent seated (2). Sedentary behaviors (i.e., waking behaviors in a seated or reclining posture <1.5 metabolic equivalents [METs]) (3) are associated with deleterious health outcomes, including an increased risk for cardiometabolic disease and early mortality (4–8). In particular, prolonged sedentary behavior, without standing or light-intensity physical activity (LPA), acutely and negatively impacts circulating blood glucose (4, 5), blood pressure (8) and musculoskeletal pain (9). Regularly interrupting sedentary time with bouts of standing (light-physical activity i.e., LPA have been shown to reduce these effects (4, 5, 8, 10–15). Therefore, an increasingly popular strategy to reduce workplace sedentary behavior is the use of sit-stand workstations, which provide desk-based office workers with the opportunity to alternate between seated and standing positions throughout the day (16). Behavioral trials incorporating sit-stand workstations have demonstrated significant reductions in workplace sitting and these effects appear sustained over 18 months (17). However, avoiding prolonged bouts of sitting (18) and sustaining frequent sit-stand workstation use over time continues to be a challenge due to the habitual nature of sitting in the workplace (19).

Point-of-choice (PoC) prompts, also known as point-of-decision prompts, are an effective tool for encouraging individuals to make more active decisions over sedentary ones (20). To date, PoC prompts have largely focused on environmental components such as stair use and have been shown to be effective for increasing physical activity (21). PoC prompts have been delivered in the workplace to interrupt prolonged sitting using visual cues, such as signage (20, 22), email reminders (23), computer software (24), and more recently, wearable devices (25). One PoC prompt study in the workplace found that prompting desk-based office workers to stand for one minute every 30 min, using computer software installed on their work computer, was effective for reducing total sitting and prolonged bouts of sitting (26). However, both the PoC prompt intervention and control group received educational benefits of reduced prolonged sitting time at the start of the study, making it difficult to conclude if findings were a direct result of prompts, or reinforcement from education. Similarly, Donath et al. (22) used computer-based PoC prompts (three times daily over 12 weeks) among those with sit-stand workstations and found marginal reductions in sedentary time via increased standing. In contrast to the prompts used by Evans et al. (26)—which simply reminded participants to take a break—the prompts used by Donath et al. (22) consisted of three different reminders, one of which indicated that "prolonged sitting is harmful" (i.e., outcome expectancies). Furthermore, in both studies, neither preference (i.e., patient choice of given characteristics of an intervention or treatment),which provides insight for intervention adoption (27), or acceptability [i.e., attitude toward the intervention or treatment options considering characteristics of the intervention; (28)] of the prompt conditions was fully assessed. Preference and acceptability are necessary constructs to assess and enhance user adherence to a treatment, satisfaction, and the validity of research. Additionally, preference and acceptability help to inform interventions and improve outcomes (28).

PoC prompts may be an effective complementary strategy to sit-stand workstation use. However, there is limited understanding regarding the effects of prompt content in this context. Previous workplace PoC prompts have been atheoretical in nature (22, 26), yet there is evidence to suggest that interventions derived from a theoretical framework may be more effective (29) and are likely to lead to more sustained behavior change. Large scale studies targeting sedentary behavior in the workplace have utilized social cognitive theory (SCT) in the development of their intervention strategies (11, 30). The framework of the SCT is relevant to the workplace environment due its triadic, reciprocal nature in which considerations are given to interactions among the environment, individual, and behavior (31). Key components of the SCT that may be efficacious for enhancing sit-stand workstation utilization include: (a) the development of self-efficacy (i.e., level of confidence in ability to exercise control over a behavior) for using the workstation; and (b) outcome expectations (i.e., individual perceptions that a given behavior will result in an outcome) for establishing benefits for engaging in standing and (c) proximal goal-setting (i.e., intentions) for success (31). Research has yet to investigate the integration of the SCT into point-of-choice prompts within the workplace. We postulate that the by integrating the SCT into a point-of-choice prompt message, behavior change may be facilitated by aiding individuals abilities to cope with barriers hindering behavior change and fostering self-efficacy and mastery to break-up their sitting time throughout their working day. As such, creating brief, unique prompts encompassing these constructs may help to facilitate proficiency in the behavior and promote long-term sustained behavior change.

The primary aim of our study was to examine the preliminary efficacy, preference, and acceptability, of two workplace PoC prompt interventions (i.e., atheoretical basic reminder [R-PoC] vs. theory-driven [TD-PoC]) for reducing sedentary time in office workers with suboptimal compliance for sit-stand workstation usage. We hypothesized prolonged sitting time at work would be reduced for both intervention conditions relative to the no-prompt control condition, and that the TD-PoC prompt condition would achieve greater reductions than that of the R-PoC prompt condition. We also hypothesized that participants would prefer and find more acceptable the TD-PoC prompt condition relative to the R-PoC prompt condition.

MATERIALS AND METHODS

Study Sample

Participants were desk-based office workers who currently have a sit-stand workstation installed at their primary office space but reported suboptimal utilization. Participants were recruited across the Phoenix metropolitan area using an information flier at the Arizona State University (ASU) Tempe and Phoenix campuses as well as several medium and large worksites. Inclusion criteria for the study were: age 18 years and older, full-time employee (>30 h/week), in office at least four days per week, in a seated position for majority of working day, had a sit-stand workstation installed at primary desk, reported using sit-stand workstation ≤4 h of the working day, and able and willing to engage in study assessment and intervention for 4 weeks. Exclusion criteria were: non-English speaking, advised by a health professional to avoid long periods of standing, and pregnant women entering or in the third trimester. All participants provided informed consent prior to participation and this study was approval by the ASU institution review board.

Study Design and Procedures

Figure 1 provides an overview of study design. We conducted a randomized cross-over trial. Enrollment and participation in this study took place from November 2017–March 2018. Total study participation lasted 30 days. Participants completed a no-prompt control condition for 5 work days to establish baseline sedentary time. Participants were then randomized to complete one of the active prompt conditions (i.e., R-PoC or TD-PoC) first. After completion of the first respective 5-day active condition, participants entered a 1-week washout period, in which they were not sent prompts and no assessment of sedentary time was collected. Participants finally entered their last 5-day active prompt condition in which they received the intervention they were not originally assigned.

Prompt Content and Administration

As displayed in **Table 1**, the R-PoC prompt condition consisted of the administration of the same single prompt: "Time to STAND!" Whereas, the TD-PoC prompt condition consisted of the distribution of 40 unique prompts encompassing SCT constructs (i.e., self-efficacy, outcome expectancies, and proximal goal setting). For both the active prompt conditions, prompts were sent eight times/day to participant emails using the web-based platform, MailChimp (Email marketing company, Atlanta, GA). These email prompts (i.e., <50 words on subject line of an email) were sent between the hours of 9:00 am and 6:00 pm with the lunch hour (i.e., 12:00 a.m.−1:00 p.m.) being avoided. Furthermore, the time within each hour (i.e., on the hour, or 15 min, 30 min, or 45 min past) each prompt was sent was randomized to avoid anticipation of the prompt. Lastly, all participants followed the same random schedule during each active prompt condition.

MEASURES

Demographics

Age, gender, height, and weight were obtained during the no-prompt control condition via an electronic survey administered using Qualtrics (Software Company, UT).

Preliminary Efficacy of Changes in Workplace Sedentary Time

To objectively assess sedentary time during all study conditions, the activPAL micro accelerometer was worn during all working days. This device is valid and reliable (32–34). We derived the following measures from the activPAL: sitting, standing, stepping, and sitting bouts >30 min, and sit-stand transitions per sedentary hour. Appropriate time-based variables were standardized to an 8-h workday. The activPAL device was waterproofed and participants were instructed to affix the device to the midline of their right thigh using hypoallergenic tape (i.e., Hypafix) and wear for five consecutive working days during the no-prompt control and active prompt conditions. Data collected from this device were processed into events of sitting, standing, or, stepping using the activPAL software (activPAL version 7.2.32 PAL Technologies Ltd, Scotland, UK). Workday arrival and departure were self-reported using a paper daily log. Any periods of continuous sitting or standing behavior >6 h as indicated by the activPAL (i.e., non-wear time) were excluded from the analyses. Wear time of at least three days with >4 h of work time was required for inclusion.

Preference of PoC Prompt Conditions

To assess preference for each PoC prompt condition, we adapted the Therapy Evaluation Questionnaire (TEQ) from the Treatment Acceptability and Preferences (TAP) measure, a valid tool for measuring preference (35). We administered the Pre-TEQ prior to each active condition to assess participant preference (i.e., preference rating for each TEQ item with a brief description of the respective condition [repetitive reminder prompt vs. unique theory-driven prompts]) of each PoC prompt intervention. The Pre-TEQ used in the present study included eight items on a 5-point Likert scale (Not at all [0] to Totally [4]). The items assessed the following: how logical the prompts seemed; how easy it would be to respond to prompts; how appropriate the prompts would be for standing; how helpful prompts would be for standing; how successful they believe the prompts would be for managing standing; how confident they were that they could stand in response to prompts; how likely they were to recommend the prompt intervention; and how important it was to make prompts available to others with a sit-stand workstation. Consistent with previous research (36, 37) we established a benchmark of ≥ 70% preference (defined as a rating of "Very" or "Totally") as a criterion of success.

Acceptability of PoC Prompt Conditions

To assess acceptability (i.e., acceptability rating for each TEQ item recalling intervention just administered), we modified the tense of the Pre-TEQ questions and administered at the end of each respective active PoC prompt condition (i.e., Post-TEQ) as recommended by (28). The benchmark of ≥ 70% acceptability (defined as a rating of "Very" or "Totally") was also used as a criterion of success.

To further assess acceptability and inform future intervention development, additional pragmatic questions were developed by the research team and assessed following each active PoC prompt condition. Participants were asked to rate the general usefulness

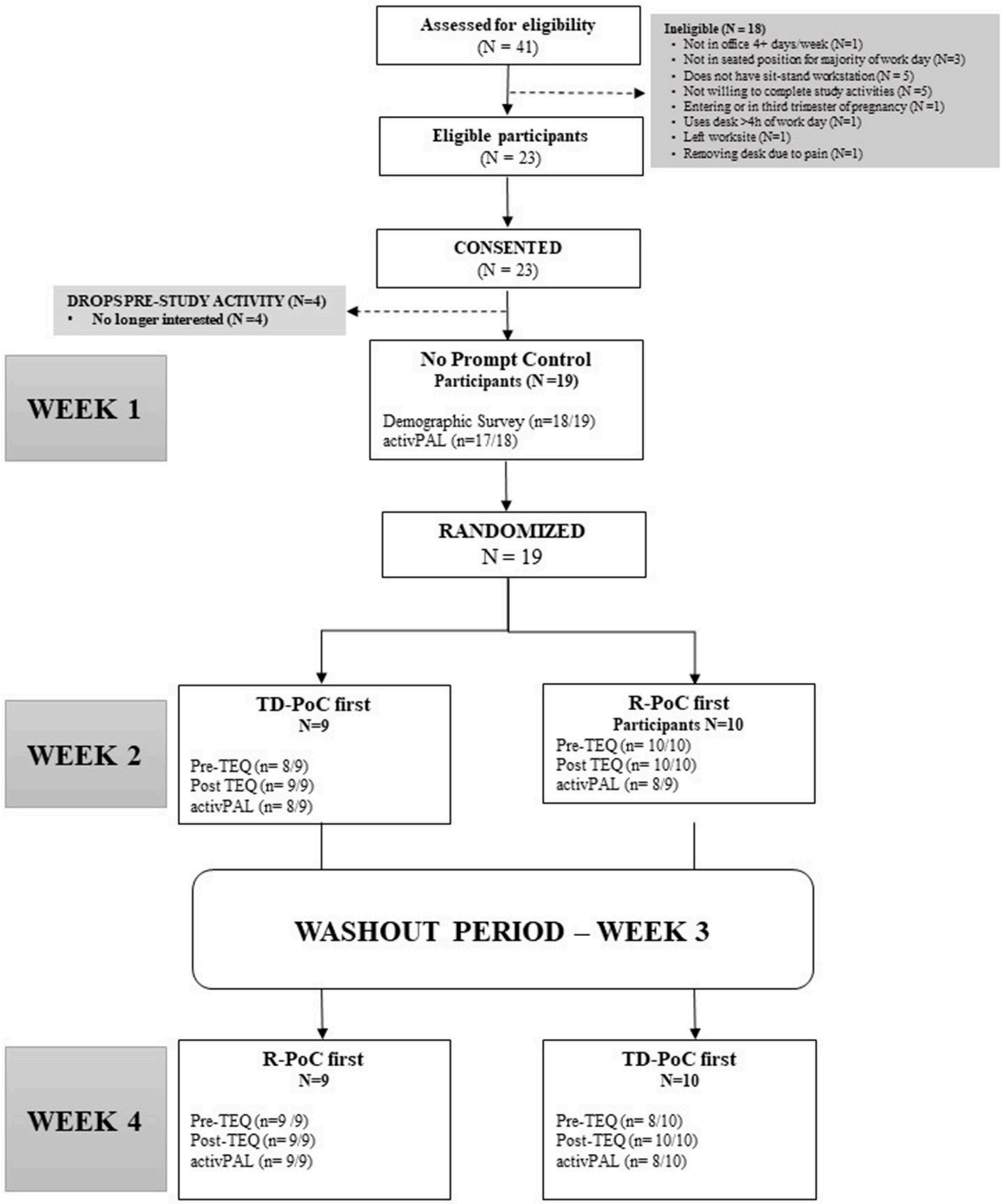

FIGURE 1 | Consort diagram.

TABLE 1 | TD-PoC prompt content and schedule.

DAY	AM/PM	TYPE	NUM.	PROMPT	Time
DAY 1	AM	SE	1	SAY IT: I have the ability to STAND while I work	0
		OE	2	Did you know? STANDing can re-energize and maintain focus	45
		SE	3	SAY IT: I CAN use my sit-stand workstation to STAND and work	30
	PM	PG	4	GOAL: STAND while you email today	15
		SE	5	SAY IT: I can STAND while I work!	0
		OE	6	Can't concentrate? STAND to clear your mind!	45
		SE	7	SAY IT: I know I will Stand at work	30
		PG	8	GOAL: STAND when someone visits your desk	15
DAY 2	AM	SE	9	SAY IT: It is MY choice to STAND and work	30
		OE	10	Break away from sitting to clear your head – STAND	15
		SE	11	SAY IT: I am STANDing more at work	0
	PM	PG	12	GOAL: STAND when your phone rings	45
		SE	13	SAY IT: I will STAND and work	45
		OE	14	Engaged muscles = improved blood flow – STAND	15
		SE	15	SAY IT: I WILL use my sit-stand workstation today	0
		PG	16	GOAL: STAND when you transition between tasks	30
DAY 3	AM	SE	17	SAY IT: I WILL balance my sitting time by STANDing	15
		OE	18	Need energy - Take a STAND	45
		SE	19	SAY IT: I WILL accomplish my goal to STAND and work	0
	PM	PG	20	GOAL: STAND while reading	30
		SE	21	Keep STANDing, look at how far you've come!	15
		OE	22	STAND up - be good to yourself	0
		SE	23	You've made it this far, don't stop now! STAND!	45
		PG	24	GOAL: STAND while you problem solve	30
DAY 4	AM	SE	25	Keep it up! Beat your sitting habit, STAND!	45
		OE	26	Stop stressing about a deadline – STAND!	30
		SE	27	You're making progress, keep STANDing while you work!	0
	PM	PG	28	GOAL: STAND for the next 5-min	15
		SE	29	Fight back against sitting, take a STAND now!	0
		OE	30	Help yourself get a good night rest – STAND	15
		SE	31	The choice is yours, sit or STAND!	30
		PG	32	GOAL: STAND for the next 10-min	45
DAY 5	AM	SE	33	Keep it going you're still STANDing	30
		OE	34	Too much sitting = poor health outcomes, STAND!	15
		SE	35	Don't let setbacks halt your progress, STAND!	45
	PM	PG	36	GOAL: STAND for the next 15-min	0
		SE	37	Continue your successes now by STANDing	15
		OE	38	Reduce your risk for diabetes - STAND!	45
		SE	39	You have CAN STAND and work	30
		PG	40	GOAL: STAND for the next 30-min	0

and frequency usefulness of the prompts, for both active PoC conditions. Furthermore, desired frequency (i.e., more or less frequently than the ∼eight prompts sent/day) and time of day (i.e., morning, afternoon, and no preference) for prompts were also assessed. Participants were also asked to recall how often they received the prompts (i.e., "approximately a few times per day (i.e., two or three)," "approximately five to seven times per day," "approximately eight times per day," "greater than eight times per day, "Never," and "I don't recall"), how frequently they noticed the prompt messages appear on their computer screen, and how frequently they responded to the prompts by standing (7-point Likert scale from "none of the time" to "all of the time"). Lastly, receipt of the prompts was objectively assessed by extracting open rates from MailChimp.

Statistical Analysis

Demographic data were summarized using means, standard deviations, frequencies, and percentages. To assess preliminary efficacy, the independent variable was condition (i.e., no-prompt control vs. TD-PoC vs. R-PoC) and the dependent variables were activPAL-measured sedentary time variables. Mixed-effects linear regression models for change were used to account for clustering of observations within participants and to determine if there were significant differences in sedentary behaviors across the three conditions. All models were adjusted for age, race, ethnicity, gender, job type, condition period (i.e., no-prompt control, R-PoC, or TD-PoC), and condition order (i.e., randomization). To assess preference and acceptability, item-level, overall score, and percent rating "Very" and "Totally" responses were summarized. McNemar tests were performed to assess between condition differences in the percent ratings. All analyses were performed using IBM SPSS Statistical Package SPSS software version 24 (IBM Analytics).

RESULTS

Study Flow and Participant Characteristics

Figure 1 presents the flow of screened and enrolled participants. A total of 41 individuals were eligible for the study with 18 ineligible (i.e., did not meet inclusion criteria, did not respond, or no interest). Twenty-three participants consented to participate; of those, four were no longer interested prior to starting the study protocol. A total of 19 participants started the trial and all completed the entire protocol. Participants reported having their sit-stand workstations for 13.1 ± 12.0 months (1 month – 48 months) prior to starting the study. **Table 2** presents demographic characteristics and **Table 3** presents objectively measured workplace sedentary and more active behaviors during the no-prompt control, basic reminder, and theory-driven conditions. In general, this sample of office workers consisted of primarily middle-aged Caucasian women who had sit-stand workstations for a minimum of 1 month prior to participation. Overall, participants had 3.6 ± 1.1 valid days with >4 h of activPAL wear time at work.

Workplace Sedentary Behavior

As displayed in **Table 4** and **Figure 2**, sitting time was significantly lower and standing time was significantly higher for the R-PoC prompt condition relative to no-prompt control. In addition, for the R-PoC prompt condition, the number of sit-stand transitions per sedentary hour was also significantly higher relative to no-prompt control. However, during both the R-PoC prompt and TD-PoC prompt conditions, time spent in prolonged sit bouts (>30 min in duration) significantly decreased relative to the no-prompt control. Total stepping time did not change for either study condition relative to the no-prompt control. For comparisons between the active study conditions (i.e., R-PoC vs. TD-PoC), no significant differences were observed, although as shown in **Figure 2**, there was a trending pattern toward more favorable results for TD-PoC prompts relative to the R-PoC prompt. Both active conditions reduced sitting time and increased standing time by >30 min/day relative to no-prompt control.

TABLE 2 | Participant characteristics.

	M ± SD/(frequency)%
Age, M ± SD	39.4 ±10.74
Female	15 (78.9)
RACE/ETHNICITY	
Non-hispanic white	15 (78.9)
Hispanic	2 (10.5)
Black	0 (0.0)
Asian	1 (5.3)
Other	1 (5.3)
JOB TYPE	
Executive	4 (21.1)
Professional	7 (36.8)
Clerical	8 (42.1)

Preference of PoC Prompts

Table 5 presents preference metrics for both the active PoC prompt conditions (assessed prior to intervention delivery). While the R-PoC prompt condition met the benchmark for the "Easy" construct only, the TD-PoC prompt condition met the 70% benchmark for the following constructs: "Logical," "Appropriate," "Recommend," and "Availability." No significant differences were observed for any items in reaching the 70% benchmark for preference.

Acceptability of PoC Prompts

Table 6 presents acceptability metrics for both the active PoC prompt conditions (assessed post intervention delivery). Both the TD-PoC and R-PoC prompt condition met the >70% benchmark for the "Logical" and "Recommend" constructs; however, the TD-PoC prompt condition also met the 70% benchmark for "Availability." Regarding additional acceptability outcomes also assessed post intervention delivery, slightly less than half of the participants rated the PoC prompts as "Very" or "Extremely useful" (i.e., "General Usefulness") in helping them to stand more with their sit-stand workstation for both PoC prompt conditions. Similar findings were seen for the frequency of the PoC prompts being useful for increased standing (i.e., "Frequency Usefulness"). Approximately half of participants rated the R-PoC prompt "Time to STAND!" as "Very Useful" or "Extremely Useful". The TD-PoC self-efficacy based prompts were only rated by a quarter of participants as "Very Useful" or "Extremely Useful"; however, more moderate ratings were displayed for the outcome expectancy based prompts, and the proximal goal based prompts, with the latter being rated the highest for both conditions. For both the R-PoC and TD-PoC prompt conditions, the majority of participants reported no time of day preference for receiving prompts however, fewer than half of R-PoC and TD-PoC participants reported that they would prefer to receive prompts in the afternoon, and <5% of R-PoC and TD-PoC participants reported wanting to receive the prompts in the morning. A high percentage of participants recalled receiving both the R-PoC and TD-PoC prompts 5–8 times/day and the vast majority reported seeing the prompts appear on their computer screen 50% or more of the time. In addition, data from MailChimp revealed that the vast majority of participants received at least seven prompts per day.

TABLE 3 | Workplace sedentary behaviors during the No-prompt control, Theory-driven PoC, and Basic Reminder PoC conditions.

	No-prompt control		Basic reminder PoC		Theory-driven PoC	
	M	**(SD)**	**M**	**(SD)**	**M**	**(SD)**
Sitting	267.9	(68.0)	251.3	(86.8)	255.5	(77.7)
Standing	170.2	(69.3)	193.2	(85.8)	185.6	(77.3)
Sit-stand transitions*	5.9	(2.1)	6.6	(3.0)	6.3	(2.2)
Sit bouts >30 min	128.7	(70.3)	106.0	(74.7)	99.5	(59.6)
Total stepping time	41.9	(16.6)	35.5	(13.2)	39.0	(8.7)

*Sitting, standing, sit bouts >30 min, and total stepping time (LPA+MVPA) are in minutes and standardized to an 8 h workday. *Sit-stand transitions are expressed as an average average per sedentary hour. LPA, light-intensity physical activity (<100 steps per minute); MVPA, moderate-vigorous physical activity (>100 steps per minute)*

TABLE 4 | Mixed-effects regression outcomes by study condition.

	Basic reminder PoC prompts vs. No prompt control			Theory-driven Poc prompts vs. No prompt control			Basic reminder PoC prompts vs. theory-driven Poc prompts		
	Beta	**(SE)**	***P***	**Beta**	**(SE)**	***P***	**Beta**	**(SE)**	***P***
Sitting	**-49.0**	**(20.8)**	**0.03**	−39.1	(20.4)	0.06	−9.9	(11.6)	0.40
Standing	**49.8**	**(19.7)**	**0.02**	34.3	(19.4)	0.09	15.5	(11.0)	0.17
Sit-stand transitions	**2.3**	**(1.1)**	**0.04**	2.0	(1.0)	0.06	−0.3	(0.6)	0.62
Sit bouts >30 min	**-68.1**	**(27.8)**	**0.02**	**-76.7**	**(27.1)**	**0.01**	8.6	(15.4)	0.58
Total stepping time	−1.7	(5.2)	0.75	3.6	(5.1)	0.49	5.2	(2.9)	0.08

Significant results are bolded. All models were adjusted for age, gender, race/ethnicity, job type, order, and period.

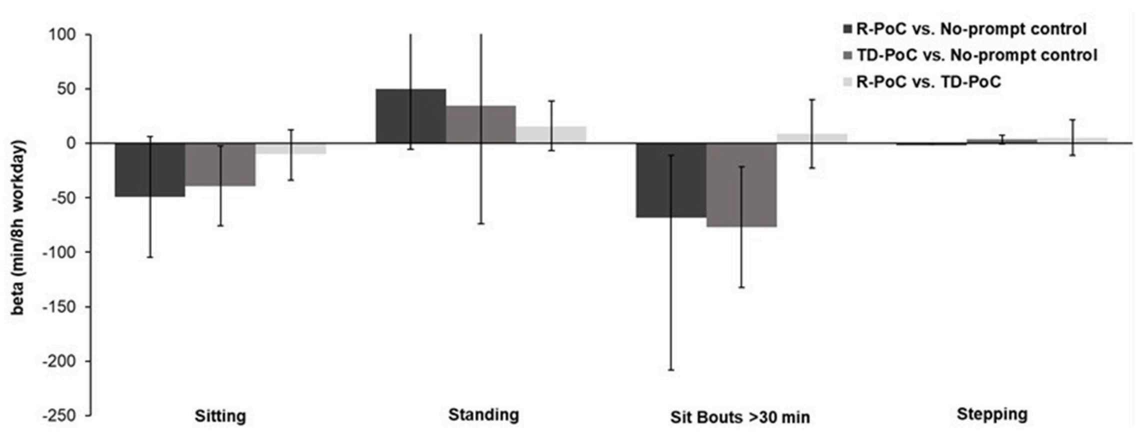

FIGURE 2 | Condition effects on sedentary behavior outcomes. Values are unstandardized beta coefficients and associated 95% confidence intervals.

DISCUSSION

The purpose of this study was to examine the preliminary efficacy, preference, and acceptability, of two PoC prompt interventions relative to no-prompt control for reducing sedentary behaviors in office workers with suboptimal utilization of their sit-stand workstations. Both prompt types appeared efficacious for reducing sedentary time and increasing standing time overall, a slight trend appeared toward greater efficacy for the R-PoC prompt condition for total sitting time, and the TD-PoC prompt condition for reducing prolonged bouts of sitting. While no significant differences between the two PoC prompt conditions were observed, the effect sizes provide both content and temporal insights that may inform future workplace sedentary behavior reduction PoC Overall, preference was slightly better for TD-PoC than R-PoC and acceptability met the 70% benchmark for some but not all metrics for TD-PoC and R-PoC prompt conditions.

Efficacy of Point-of-Choice Prompts in Sit-Stand Workstation Users

Similar to previous findings, the reminder prompts which used repetitive content "Time to STAND!," resulted in a significant decrease in sitting time and increase in standing time relative to no-prompt control (22, 26, 38). However, contrary to our hypotheses, TD-PoC prompts only elicited significant reductions in prolonged sitting bouts (>30 min of continuous sitting) relative to the no-prompt control. Further, the TD-PoC prompts and were less efficacious than basic reminders for sitting and standing time outcomes. These contradictory findings may be attributed to differences in prompts dosage, sample population, study duration, PoC prompt content, and specificity of behavioral targets.

Point-of-Choice Prompt Dosage and Duration

While the duration of this study was the same as Evans et al. (26), prompt dosage (i.e., once every 30-min for 1 min) was higher than ours, and this may have implications for efficacy of a higher prompt dose needed to elicit greater reductions in total sitting time as well as prolonged sit bouts. Similarly, the lower average daily sedentary time (measured during the no-prompt control condition) in our study may have contributed to these conflicting findings. However, it is important to note that the reduction in total sitting time was similar between conditions. In addition, the prompting software used by Evans et al. (26) maintained on participants computer screens for 1 min, whereas the prompts in the present study and others (22) could easily be missed if not looking directly at one's computer screen. Therefore, it may be necessary to have prompts appear for a minimum amount of time to properly serve as a visual cue. Additionally, a higher PoC prompt dose may prove to be beneficial considering literature displaying breaks in prolonged sitting time being beneficial for metabolic risk and it may be of necessity given the habitual nature of sedentary behaviors.

It is difficult to judge whether duration of the intervention may have impacted the results, though past research has shown decreases in sitting time during brief 3-day (25) and 5-day (26) intervention periods. Longer duration interventions and studies with follow-up periods may provide insight into whether PoC prompts are needed for long-term sustain standing behaviors, or if there is a minimum time-period required to elicit independent behavior change. Conducting longer duration interventions may provide insight as to whether there is a trend for office-workers to return to habitual sitting durations after the removal of prompts and are of important consideration for fostering behavior change that can be sustained independently.

PoC Prompt Content and Specificity of Behavioral Targets

This study focused on the PoC prompts as a complementary strategy to facilitate sit-stand workstation use, which is conducive to standing behavior. The contextual specificity of the reminder prompt ("Time to STAND!") and behavioral target (standing) may partially account for the increased standing time and notably, the significant decrease in prolonged sit bouts (≥30 min). In contrast, the TD-PoC prompts included a broader range of messages (i.e., 40 unique prompts) that encompassed behavior change tactics from the social cognitive theory (i.e., self-efficacy, outcome expectations, and proximal goal setting) that largely focused on not only standing more, but the importance of reducing prolonged sitting bouts. In support of the "usefulness" results (**Table 4**), the significant decrease in prolonged sit bouts observed for the TD-PoC condition compared to no-prompt control, may be largely driven by the perceived consequences of performing or not performing sedentary behaviors (i.e., outcome expectations) and behavioral targets (i.e., proximal goal setting), designed to foster active behaviors while working. These findings may further strengthen the argument for developing and implementing tailored interventions that leverage specific types of prompts (e.g., basic reminder vs. theory-driven health outcome specific) to focus on different aspects of sedentary behaviors (e.g., standing vs. reduced prolonged sitting bouts).

TABLE 5 | Point-of-choice study conditions preference.

	Preference (Pre-TEQ)			
	Basic reminder PoC prompt		Theory-driven PoC prompts	
	M (SD)	Benchmark >70%	M(SD)	Benchmark >70%
Logical	3.1 (0.3)	66.7	3.4 (0.1)	**93.8**
Easy	2.9 (0.3)	**73.7**	2.9 (0.1)	68.8
Appropriate	2.8 (0.4)	63.2	3.3 (0.3)	**87.5**
Helpful	2.5 (0.6)	52.6	2.8 (0.1)	68.8
Successful	2.3 (0.3)	47.4	2.7 (0.1)	62.5
Confident	2.8 (0.3)	68.4	2.6 (0.1)	56.3
Recommend	2.7 (0.5)	68.4	3.3 (0.1)	**93.8**
Availability	2.5 (0.4)	52.6	3.1 (0.1)	**87.5**
Total TEQ Score	2.7 (0.4)	61.6	3.0 (0.1)	**77.3**

Item ranges were all 1–5. Preference was assessed prior to intervention delivery. Preference score meeting the >70% success criterion are bolded. All pairwise comparisons between basic reminder PoC prompt vs. theory-drive PoC prompt and pre TEQ vs. post TEQ were non-significant (p's > 0.05).

Implications of Preference and Acceptability of PoC Prompt Findings

Implications for PoC Prompt Content

Prior to the intervention, participants reported preferring TD-PoC prompt content compared to basic reminders. As preference may be used as an early indicator of intervention adoption, this may suggest greater chances for cultivating sustained behavior change (28). The use of multiple observations (i.e., pre and post) throughout the present study duration of future PoC based studies allows for richer examination of fluctuations in prompt content preference.

The TD-PoC prompt content was also rated as more acceptable than the basic R-PoC prompt content, replicating trends observed for preference. However, the trajectory of the TEQ results from pre-to-post indicated a ~10% decline in the TD-PoC content due to lower acceptability ratings, whereas the reminder content displayed a marginal increase (i.e., ~2%) from pre-to-post TEQ scores. We postulate that the trend for the interventions to be rated more similarly at post-test may be due an initial perception of the "unique" theory-driven intervention being perceived as more efficacious than one including basic "repetitive" reminder prompts. However, post-intervention delivery, participants may have concluded that a basic reminder may be sufficient for prompting standing

TABLE 6 | Point-of-choice study conditions acceptability.

	Basic reminder PoC prompt		Theory-driven Poc prompts	
	M(SD)	Benchmark >70%	M (SD)	Benchmark >70%
Logical	3.3 (0.4)	**84.2**	3.1 (0.3)	**73.7**
Easy	2.6 (0.2)	63.2	2.7 (0.0)	68.4
Appropriate	3.1 (0.5)	68.4	2.9 (0.3)	68.4
Helpful	2.4 (0.6)	47.4	2.5 (0.4)	63.2
Successful	2.2 (0.6)	47.4	2.2 (0.1)	47.4
Confident	2.7 (0.3)	63.2	2.8 (0.2)	68.4
Recommend	3.0 (0.4)	**73.7**	2.9 (0.3)	**72.2**
Availability	2.6 (0.4)	57.9	2.8 (0.3)	**73.7**
Total TEQ Score	2.7 (0.4)	63.2	2.7 (0.2)	68.9
General usefulness	2.2 (1.3)	42.1	3.7 (1.7)	47.4
Frequency usefulness	2.3 (1.3)	47.4	2.3 (1.2)	42.1
Reminder usefulness	2.3(1.3)	52.6	–	–
SE usefulness	–	–	1.5 (1.3)	26.3
OE usefulness	–	–	2.2 (1.1)	42.1
PG usefulness	–	–	2.4 (1.2)	63.2

All acceptability ranges were 0-4; SE, self-efficacy; OE, outcome expectations; PG = proximal goal; Acceptability was assessed following intervention delivery. Acceptability scores meeting the >70% success criteria are bolded. All pairwise comparisons between basic reminder PoC prompt vs. theory-driven PoC prompts were non-significant (p's > 0.05).

behavior. Furthermore, these results were supported by the additional acceptability questions, beyond the TEQ measure, which exhibited similar perceived usefulness ratings across both conditions also assessed following each active condition.

Interestingly, for individual ratings of the TD-PoC prompt content post condition delivery, proximal goals were perceived as most useful and self-efficacy content was perceived as least useful. We posit that due to the habitual nature of sitting and simplicity of the intervention behavioral target (moving from a seated to standing position with an existing sit-stand workstation), self-efficacy prompt content may not be necessary to facilitate sit-stand transitions beyond the start of the intervention. Alternatively, setting proximal goals to guide sit-stand workstation use over time may be more valuable for long term behavior change. Consequently, prompt content may need to evolve over the intervention delivery period, including both TD-PoC content alongside regular reminders at the start of the intervention, and over time, transitioning to basic reminders only.

Implications for Temporal Decisions Regarding PoC Prompts

Across both prompt conditions, the additional acceptability assessment post condition delivery revealed that about half of the participants were least receptive to receiving prompts in the morning and most receptive to receiving prompts in the afternoon. This is consistent with anecdotal reports of participants indicating that persons are more motivated to stand in the morning; however, fatigue may inhibit standing as the day goes on (16). Alternatively, nearly 50% of the participants reported "no preference" regarding the time of day. Given the habitual nature of sitting, it may be difficult for participants to "recollect" the time(s) at which they are likely to sit for prolonged periods. Further examination of workplace sedentary time trajectories is required to better understand when prompts may be most effective, considering both opportunity and receptivity.

Further assessment post condition delivery revealed that most participants reported that the frequency of the TD-PoC prompts was appropriate compared to the reminder prompts. Interestingly, a higher proportion of participants reported that they would prefer to receive prompts more frequently for both the R-PoC and TD-PoC conditions. These results support a likely need for tailored interventions that may incorporate real-time feedback whenever possible to promote behavior change (39). Researchers can use such real-time feedback to detect prolonged bouts of sitting, which are of particular importance in workplace settings where there are greater opportunities. Individuals may be more receptive to these types of interventions given variations in busyness and workload are likely. Automatic detection of prolonged sitting may also overcome the potential for negative feedback of prompting someone to stand when they are already standing.

Strengths and Limitations

Strengths of our study include the randomized cross-over trial design and 1-week wash-out period, providing a balance between the R-PoC and TD-PoC prompt conditions and reducing potential carry-over effects between the two interventions. Participants also had their sit-stand workstation for at least 1 month (range of 1–48 months) prior to starting the intervention, possibly minimizing workstation specific novelty effects. Objective measures of sedentary and more active behaviors were assessed. This study also utilized objective measures of prompt engagement (i.e., delivery and open rates), allowing for implementation measurement. Finally, other studies (25, 26, 38, 40) have generally examined the effectiveness of interventions without assessing preferences and acceptability, potentially limiting the ability to achieve important knowledge that can further enhance, develop, and establish an intervention as evidence-based for future implementation and dissemination. Assessing these factors is important for the development of evidence-based interventions and to help researchers to understand the probability of an intervention being efficacious (36). Limitations of this study include relatively sample size. Participants in this study were mostly university staff, primarily women, who volunteered to participate and therefore may not be representative of other non-volunteer office workers. Also, this was a short-term study, so longer efficacy of PoC prompts in this context remains unknown.

Future Directions

Future studies further examining the preliminary efficacy, preference, or acceptability of using prompts to increase sit-stand workstation utilization should consider the below adaptations to enhance study design.

- Larger sample size
- Recruitment across sectors (i.e., government, industry, academia)
- Feedback and integration with worksite wellness personnel
- Education on health implications
- Incorporation of real-time feedback (i.e., wearable devices and proximity sensors)
- Prompt delivery modality (i.e., computer software, email, or text-messaging)
- Determination of optimal prompt dosage/day

CONCLUSION

This study highlights the potential efficacy of utilizing point-of-choice prompts to reduce sedentary behaviors in desk-based office workers with suboptimal reported sit-stand workstation usage. While a basic reminder prompt may be sufficient to elicit reductions in sedentary behaviors during this short-term study, theory-driven point of choice prompts may prove to be beneficial for driving reductions in specific behaviors sedentary behaviors (e.g., reduced sitting time vs. reduced time spent in prolonged sitting bouts). Interestingly, despite the theory-driven point of choice prompt condition having higher total preference and acceptability scores, the basic reminder point of choice prompt condition displayed a significant reduction in sitting time and significant increase in standing time compared to the theory-driven point of choice prompt condition.

AUTHOR CONTRIBUTIONS

All authors contributed to study design. ML was responsible for data collection, analysis, and manuscript preparation. SM, MT, MP, JH, BA, and MB reviewed and edited the manuscript, and approved the final version prior to submission.

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Sedentariness: A Need for a Definition

Valentin Magnon[1], Frédéric Dutheil[2,3] and Catherine Auxiette[4]*

[1] Université Clermont Auvergne, UFR de Psychologie, Sciences Sociales, Sciences de l'Éducation, CNRS, LaPSCo, Clermont-Ferrand, France, [2] Université Clermont Auvergne, CNRS, LaPSCo, Physiological and Psychosocial Stress, University Hospital of Clermont-Ferrand, CHU Clermont-Ferrand, Preventive and Occupational Medicine, WittyFit, Clermont-Ferrand, France, [3] Faculty of Health, School of Exercise Science, Australian Catholic University, Melbourne, VIC, Australia, [4] Université Clermont Auvergne, CNRS, LaPSCo, Clermont-Ferrand, France

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Sedentary behavior is a growing field of research which is now recognized as a public health issue (1). Sedentary comes from the latin term "sedere," which means "to sit." Many researchers have shown that remaining seated for prolonged periods of time can lead to several detrimental health effects at the physiological level [see (2) for a systematic review], such as an increased risk of developing cardiovascular disease (3–5), type 2 diabetes (3, 4, 6), obesity (4, 7), some cancers (8, 9), or musculoskeletal disorders (10, 11). It also has detrimental effects at the psychological level, such as depression (12–14), anxiety (14–16), or cognitive decline [(17–19); for a review, see (20)]. However, there is no consensus in the physiological results (for contradictory results concerning cardiovascular disease and type 2 diabetes, see (21, 22), respectively), and psychological results are still not consistent for depression (23), anxiety (24), or cognitive decline (17). More research is therefore needed to further understand the implications of sedentary behavior on both physiological (25) and psychological health (17).

Sedentary behavior has been defined in many ways over the years, but mostly by using energy expenditure, i.e., any behavior where energy expenditure is strictly below 2 METs (Metabolic Equivalent Tasks) (26), or between 1 MET and 1.8 METs (27). However, that criterion alone is not enough to clarify what sedentary behavior is. Indeed, standing has an energy cost close to sitting (28), without causing any of the detrimental health effects of sedentary behavior. For instance, breaking up prolonged sitting times by standing for a few minutes has a positive impact on postprandial glucose metabolism (29–31). However, there is no consensus for these results (32–34). Posture therefore must be taken into account to distinguish a standing up position from sedentary behavior. Currently, the terminology consensus project from the sedentary behavior research network [SBRN, (35)] defines sedentary behavior as "*any waking behavior characterized by an energy expenditure ≤1.5 METs, while in a sitting, reclining or lying posture.*" This definition excludes a standing position as sedentary behavior and grants a better understanding of what sedentary behaviors are, and what differentiates them from others.

However, this recent definition may not be enough to reveal the complexity of sedentariness as a way of life. Indeed, it refers to behaviors adopted at a specific time but without providing any long-term information. It does not grant a better understanding of what a sedentary lifestyle is and what its characteristics are. Thus, it fails to define what a sedentary lifestyle is, whereas such a definition has been given for physical (in)activity. According to the WHO recommendations (36), healthy adults "*should do at least 150 minutes of moderate-intensity aerobic physical activity throughout the week, or do at least 75 minutes of vigorous-intensity aerobic physical activity throughout the week, or an equivalent combination of moderate-and vigorous-intensity activity. Aerobic activity should be performed in bouts of at least 10 minutes duration.*" Yet around one third of the world's population (37) and 55 to 70% of the US population over 65 (38) do not meet these guidelines, which is detrimental to health. For example, in the general population, physical inactivity is independently related to an increased risk of obesity (39), type 2 diabetes (40, 41), some cancers (42, 43), shortened

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Edited by:
Daniel P. Bailey,
University of Bedfordshire Bedford,
United Kingdom

Reviewed by:
Céline Aguer,
Institut du Savoir Montfort (ISM),
Canada

****Correspondence:***
Catherine Auxiette
catherine.auxiette@uca.fr

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life expectancy (42, 44), and risks of mental health problems (45, 46). In Canada, physical inactivity represents nearly 3% of the overall health care costs (47) and has been recognized as a worldwide economic burden (48). These cut-offs in physical activity allow a distinction to be made between physically active individuals and physically inactive ones. They would also be useful in the definition of sedentary behaviors, but they have not yet been integrated.

Only taking into account the energy expenditure and the posture is not enough when one is interested in the lifestyle of an individual. A sedentary lifestyle cannot be reduced to physical inactivity. Regardless of the confusion between the two terms (4, 49, 50), physical inactivity and sedentary behavior can be considered as independent, because their physiological consequences on health are not the same. For example, sedentary behavior leads to an increased risk of mortality (1, 51–53), irrespective of the amount of physical activity practiced. A person can meet the guidelines regarding physical activity and still be considered as sedentary if they spend a large amount of their day sitting or lying down at home, at school, at work, driving, or during their leisure time. It is therefore important to distinguish physical inactivity from sedentariness.

Defining what sedentariness is as a lifestyle would be complementary to the definition of sedentary behavior at any given moment. Furthermore, defining sedentariness as a lifestyle is an essential step in proposing recommendations when they are needed (as for physical activity), which could have a positive impact on the quality of life (i.e., physical, psychological, and social health and, hence, the overall health of an individual) (54). However, studying sedentariness is complex since several factors may influence the relationship between sedentary behavior and mental or physical health, such as the *type of sedentary activities*. For instance, strong evidence has been found regarding the association between cardiovascular diseases and TV viewing, total sitting time and screen time. However, evidence is weak for occupational sitting (25). Regarding psychological outcomes, cognitively demanding activities (e.g., sitting while reading, actively using a computer) are associated with better executive performances such as working memory (55, 56), mental flexibility (56) and visual spatial memory (55), while TV viewing is negatively associated with such executive performances among adults (55, 56). Moreover, physical activity and sedentariness might be two factors influencing each other in the long term (57–59). High levels of moderately intensive physical activity might attenuate the increased risk of death associated with high sitting times (57). Thus, when investigating sedentariness, the *level of physical activity* might also be considered. The same applies for *age*, since older individuals have been sedentary for longer periods of time than younger ones (60). A fourth factor to consider is the *interruption of sedentary bouts*. Health benefits have been demonstrated by breaking sedentary behavior every 20 (61, 62) or 30 min (6, 30, 63, 64). Yet, there is no consensus on the preferential frequency for breaking up sedentary time. Therefore, more studies are needed in order to gain a better understanding of the full scope of the consequences of sedentary behavior on health and at which point those consequences might be detrimental in the long term.

As mentioned earlier, thresholds would be useful in the definition of sedentariness as a lifestyle as it would allow sedentary individuals to be distinguished from non-sedentary ones. According to the Australian government (65), the cut-off point for mortality risk is approximately 7 or 8 h a day. Likewise, a meta-analysis on 6 studies among adults reported that sitting for more than 7 h a day is associated with an increased mortality risk (66). However, this meta-analysis disagrees with another which was (57) conducted on 13 studies and which revealed that sitting for more than 4 h a day is enough to increase the risk of all-cause mortality among adults. This inconsistency could be explained by the way in which sedentary behaviors are evaluated, as the evaluations were objective in some cases (e.g., with accelerometers), but subjective in others (questionnaires). However, questionnaires tend to underestimate total sedentary time (67, 68) compared to objective measures (18). This hypothesis was supported by a meta-regression analysis (69) which showed that the cut-off of daily sedentary time for self-reporting studies was 7 h/day compared with 9 h/day for device-based ones.

This lack of consensus has led researchers to use different criteria to define a sedentary lifestyle, making comparisons of the results difficult. A common definition of sedentariness would improve its study and the determination of the potentially detrimental consequences on the physiology, as well as other aspects that would impact the quality of life of individuals and their well-being. For example, sitting for less than 8 h a day is associated with higher perceived mental health and vitality scores (54) and lower anxiety (16, 54) and depression scores (13, 54).

Another example is the potential relationship between sedentary behavior and the increased risk of dementia (70), which currently lacks sufficient evidence (17). Recommendations for a sedentary lifestyle would enable the relationship between sitting time and an increased risk of dementia to be studied. If sedentariness is a risk factor for cognitive decline (18) and dementia (17, 70), then guidelines for sedentariness would grant the possibility of developing efficient intervention protocols in order to decrease sedentariness and make modern lifestyles healthier. Such interventions would reduce the high prevalence of dementia (71) and its economic cost (72). Therefore, a definition of sedentariness would provide a better understanding of this lifestyle and its physiological, psychological, economic and social implications. This definition should at least take into account the type of current and past sedentary activities (cognitively demanding vs. undemanding activities) and their duration, the type of current and past physical activity (low, moderate, vigorous), the way sedentarity is measured (objective measurements as far as possible), the interruption of sedentary bouts, and age.

AUTHOR CONTRIBUTIONS

VM reviewed the literature, created, and maintained a Zotero database, wrote the initial manuscript, and revised the second drafts following feedback from CA and FD. CA reviewed the literature. Both CA and FD made editorial suggestions for the second drafts. All authors contributed to manuscript revision, read and approved the submitted version.

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Even a Previous Light-Active Physical Activity at Work Still Reduces Late Myocardial Infarction and Stroke in Retired Adults Aged>65 Years by 32%: The PROOF Cohort Study

David Hupin[1,2*], *Jérémy Raffin*[1,3], *Nathalie Barth*[1], *Mathieu Berger*[1], *Martin Garet*[1], *Kevin Stampone*[4], *Sébastien Celle*[1,2], *Vincent Pichot*[1,2], *Bienvenu Bongue*[1,5,6], *Jean-Claude Barthelemy*[1,2,7] *and Frédéric Roche*[1,2]

[1] UJM-Saint-Etienne Autonomic Nervous System Research Laboratory, EA 4607 SNA-EPIS, Univ. Lyon, Saint-Etienne, France, [2] Department of Clinical and Exercise Physiology, University Hospital of Saint-Etienne, Saint-Etienne, France, [3] Loire-Haute Loire French Mutuality, SSAM, Saint-Etienne, France, [4] Faculty of Medicine, UJM-Saint-Etienne, Univ. Lyon, Saint-Etienne, France, [5] UJM-Saint-Etienne, Chaire Santé des Ainés, Univ. Lyon, Saint-Etienne, France, [6] Support and Education Technic Centre of Health Examination Centres (CETAF), Saint-Etienne, France, [7] French Federation of Voluntary Gymnastics (FFEPGV), Montreuil, France

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***Correspondence:**
David Hupin
d.hupin@univ-st-etienne.fr

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Background: Work may contribute significantly to daily physical activity (PA) and sedentary behavior (SB). Physical inactivity and SB at work might be two major risk factors for premature morbidity. Therefore, the aim of this research was to describe self-reported past PA and SB at work and during leisure time within the PROOF cohort subjects, and to determine consequences of PA and SB on late health of these now retired workers.

Material and Methods: The PROOF cohort study was used to prospectively allow assessment of the predictive value of PA and SB at work and during leisure time among a healthy retired French population, with regard to cardiovascular and cerebrovascular events. PA (MET-h/week) and SB (h/d) were assessed using the Population Physical Activity Questionnaire (POPAQ) and the modified Global Physical Activity Questionnaire (GPAQ). Odds ratios (ORs with 95% CIs) for cardiovascular and cerebrovascular events were associated with each level of PA at work: light (<3 METs), moderate (3–5.9 METs), vigorous (≥6 METs) and were compared to SB at work.

Results: Out of the 1011 65-year-old subjects initially included, the 15-year follow-up has been currently completed for 688 (68%) subjects; 89 deaths (all-cause mortality, 9%) and 91 fatal and non-fatal cardiovascular and cerebrovascular events (9%), were reported. An active work (light, moderate, or vigorous intensity) was associated with a 21% reduced risk of cardiovascular (myocardial infarction) and cerebrovascular events (stroke) (OR = 0.79, 95% CI: 0.32–0.91, $p < 0.02$) compared to sedentary work. This relationship was already significant for light intensity work (32%; i.e., OR = 0.68, 95% CI: 0.31–0.87, $p < 0.02$).

Conclusion: There is strong causal evidence linking PA and SB at work with late cardiovascular and cerebrovascular disease. All in all, the risk for onset of myocardial infarction and stroke was lower among those who had a previous active work compared to those with previous sedentary work. Even previous light active work produced substantial health benefits.

Clinical Trial Registration: www.ClinicalTrials.gov, identifier: NCT00759304.

Keywords: physical activity, sedentary behavior, work, prevention, health, cardiovascular event, cerebrovascular event, global physical activity questionnaire

BACKGROUND

Studies from Morris et al. in the 1950s have stimulated a significant interest in understanding the relationship between physical activity (PA) and sedentary behavior (SB) at work (1). Since then, some researchers followed this twentieth century visionary with new cohort studies, which have shown that physical inactivity and SB at work are two major risk factors for morbidity and premature mortality (2–10). Transition to retirement is an important turning point in life of previously sedentary and inactive people. Indeed, a minor change in PA and SB might lead to significant health benefits (11). However, many aspects of these relationships are still poorly studied. We know that regular PA and a less sedentary lifestyle are an effective strategy for successful aging (12). A key question is the following: if one is active at work, will one always stay active during retirement? If yes, what is the eventual late health benefits? If not, what will this imply to one's health? The aim of this research was thus to describe self-reported PA and SB at work and during leisure time within the PROOF (Prognostic indicator of cardiovascular and cerebrovascular events; *ClinicalTrials.gov identifier: NCT00759304*) cohort subjects, then to determine their consequences on late health of retired workers.

MATERIALS AND METHODS

An Observational Study: The PROOF Cohort

The PROOF cohort study was designed to prospectively assess the predictive value of autonomic nervous system activity level among a healthy retired French population, with regard to cardiovascular events and mortality (13). Subjects were recruited amongst the inhabitants of the city of Saint-Etienne, France and were eligible if aged 65 at the inclusion date. The study excluded people living in institutions. This entry age was selected since it coincides with the most frequent retirement age and consequently to the start of a new lifestyle allowing better quantification of lifestyle parameters. The PROOF study was approved by the University Hospital and the IRB-IEC (CCPRB Rhône-Alpes Loire). The National Committee for Information and Liberty (CNIL) gave its consent for data collection. All the subjects signed an informed consent for the study.

Physical Activity and Sedentary Behavior Assessments

PA and SB were assessed during the cohort follow-up every 3 years since 2001 using (i) the Population Physical Activity Questionnaire (POPAQ) and in 2014 using (ii) the modified Global Physical Activity Questionnaire (GPAQ) for past PA and SB.

POPAQ

The POPAQ explored the seven main dimensions of everyday life over a period of 7 days, with added specific consideration for sedentary behaviors and leisure time physical activities in our study (13). This questionnaire, validated against doubly labeled water technique and maximal oxygen consumption, was designed to provide a complete picture of a subject's usual PA (14, 15).

GPAQ

The GPAQ was developed in 2002 by the World Health Organization (WHO) as part of the WHO STEPwise Approach to Chronic Disease Risk Factor Surveillance for PA observation. A self-administered format of the GPAQ was developed based on the original version of the GPAQ in French (available at www.who.int/ncds/surveillance/steps/GPAQ_Analysis_Guide_FR.pdf). The GPAQ, validated against accelerometry (16–18), consisted of 16 questions designed to estimate an individual's level of PA in 3 domains, with added specific consideration for work, leisure time and time spent in SB in our study. The modified version by authors was adapted from the initial self-administered questionnaire by adding an assessment of SB and each PA domain at different ages: 15, 30, 60, and 80, without rewording sentences of the validated administered version.

These questionnaires were sent by post and were self-administered in approximately 15 min. Subjects filled out the questionnaire by completing the time spent in each activity, quantifying the number of times the activity was done in a week or a day. Investigators (DH and MG) had thereafter to code the questionnaire using a specific written computer spreadsheet. GPAQ data were analyzed according to the GPAQ analysis guide of the WHO.

SB was quantified according to the number of hours/day spent sitting. PA was measured in Metabolic Equivalent of Task (MET)-minutes, which refers to the amount of energy (calories) expended per minute of PA (19). On the basis of the Ainsworth's compendium of PA, resting energy expenditure is assumed to be 1 MET. PA of 3–5.9 metabolic units (METs), is defined as moderate and PA ≥ 6 METs is considered as vigorous (19). MET values were applied to moderate (4 METs) and vigorous (8 METs) intensity variables in the work and recreation settings. These have been calculated using an average of the typical types of activity. Applying MET values to activity levels allowed us to calculate total PA expenditure. A combination of 4 METs PA for 15 min and a 6 METs PA for 15 min 5 days a week is equivalent to 750 MET-min/week.

Fatal and Non-fatal Cardiovascular and Cerebrovascular Events Assessment

For each survey, participants received an invitation by post. Appointments were then made by phone. If the subjects did not contact us, they were contacted by phone. Medical history and examinations were taken during each clinical visit to the research center to determine clinical events and missing information obtained from hospital chart reviews and questionnaires sent to family practitioners (13).

All cause, cardiovascular and cerebrovascular mortality were established using the same procedure and by checking the national death registry for every missed medical examination. Death certificates were individually analyzed. Late fatal or non-fatal events continued to be monitored after the examination programs. In addition, new onset of cardiovascular (myocardial infarction) and cerebrovascular (stroke) events were checked for and updated at each clinical visit (13).

Data were collected on paper forms and an independent research group entered the data to ensure a double-blind data capture. The resulting database was analyzed by a statistician to identify outliers and inconsistencies. Discrepancies were then checked using the subject forms by a medical doctor to ensure statistical and medical coherence.

Statistical Analysis

The population characteristics were analyzed using descriptive statistics and were reported as mean (±median) and frequencies (%). Chi-square was used for qualitative variables and Students *t*-test, or Wilcoxon test, for quantitative variables as appropriate. Intergroup analysis (15–30–60–80) was performed using Mann-Whitney test.

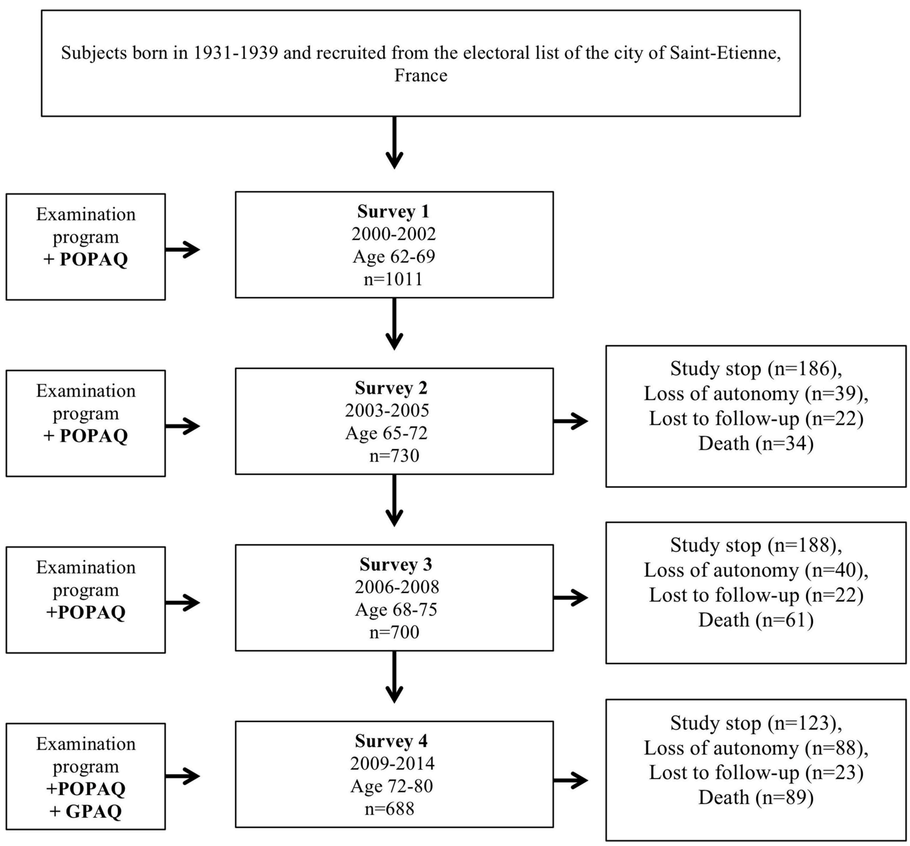

FIGURE 1 | PROOF cohort study flowchart. Deaths presented as cumulative mortality from beginning of the follow-up of the cohort. Study stop represents those who did not wish to continue the study. They did not contribute information on examination program at that survey but they could return at later survey if they had changed idea. POPAQ: Population Physical Activity Questionnaire. GPAQ: Global Physical Activity Questionnaire.

Odds ratios (OR with 95% confidence intervals, Cis 95%) for cardiovascular and cerebrovascular events (myocardial infarction or stroke) were associated with (i) each level of PA at work in early life: light (< 3 METs), moderate (3–5.9 METs) and vigorous (≥ 6 METs) using chi-squared and linear regression. These data from GPAQ were compared to SB at work (reference group for which the OR was set at 1), with (ii) changes in PA at the age of 65 years. Subjects who increased or maintained their level of PA were compared to subjects who decreased their level of PA and vice versa according to POPAQ data, with (iii) changes of SB at the age of 65 years. Subjects who decreased or maintained their sedentary time were compared to subjects who increased their sedentary time and vice versa according to POPAQ data.

Changes in PA or SB were quantified as current reported value minus previous reported value for each subject at each scheduled follow-up survey (2, 3, and 4). Thus among subjects who self-reported a myocardial infarction or a stroke, change in PA or SB was measured before and in close proximity (i.e., within 3 years, which corresponded at 1 survey) of the reported cardiovascular and cerebrovascular events. For subjects with missing PA or SB data at the previous time point, the survey prior to that was selected to capture change, but only up to 1 survey prior. For instance, if a subject was missing survey 3, then change at survey 4 was quantified as survey 4 minus survey 2; however, change at survey 3 was still regarded as missing. Analyses were conducted with and without using the previous time point for missing cases to ensure consistency in results. Multivariate logistic regression analysis was performed to estimate adjusted 95% ORs. The explanatory variables were gender, age and CVD risk factors including hypertension, dyslipidemia, diabetes mellitus, overweight (BMI > 25) and smoking. All explanatory variables with $p < 0.2$ were included into the multivariate models, which were calculated using backward by elimination of non-significant variables.

Statistics were performed on R (R development Core Team, 2018), where $p < 0.05$ was considered statistically significant. All tests were two-sided.

RESULTS

Out of the 1011 65-year-old subjects initially included, the 15-year follow-up has been currently completed for 688 (68%) subjects; 89 deaths (all-cause mortality, 9%) and 91 fatal and non-fatal cardiovascular and cerebrovascular events (9%) were reported. Among the 234 remaining subjects who did not attend the last follow-up, 123 (12%) did not wish to continue the study, 88 (9%) were excluded for loss of autonomy and living in an institution (exclusion criteria), and 23 (2%) were lost to follow-up without obvious cause (**Figure 1**).

A majority of women (75%) were included the cohort. Sedentary work was the most represented (40% at 60 years of

TABLE 1 | Description of the population *(%, mean and SD)*.

Variables	Age				P^*
	15*	30	60	80*	
	N = 688				
Women, *n (%)*/Men, *n (%)*	514 (75%)/174 (25%)				
***N* (%)**					
Sedentary work	247 (36)	206 (16)	275 (40)	287 (42)	
Light intensity work	220 (32)	228 (18)	248 (36)	242 (35)	
Moderate intensity work	138 (20)	165 (24)	110 (16)	108 (16)	
Vigorous intensity work	83 (12)	89 (13)	55 (8)	51 (7)	
Moderate-to-vigorous physical activity, *MEAN (± MEDIAN) MET-min/week*					
Sedentary work	2,203 (2022)	2,075 (2198)	1,833 (2004)	1,573 (1660)	–
Light intensity work	2,806 (2725)	4,410 (4352)	4,084 (3987)	3,060 (3163)	0.02
Moderate intensity work	6,367 (5321)	8,565 (7543)	5,635 (4790)	4,777 (4123)	0.009
Vigorous intensity work	7,506 (6988)	12,495 (6764)	8,722 (7123)	6,452 (6213)	0.01
Sedentary behavior, *MEAN (±MEDIAN) h/d*					
Sedentary work	3.3 (3.6)	3.9 (4.4)	4.5 (3.7)	6.0 (4.7)	–
Light intensity work	3.5 (3.8)	3.8 (4.0)	3.9 (3.8)	4.3 (3.9)	0.2
Moderate intensity work	3.0 (3.0)	2.9 (3.0)	4.2 (3.9)	4.8 (4.1)	0.005
Vigorous intensity work	2.7 (2.5)	2.7 (2.9)	3.3 (3.5)	4.6 (4.0)	0.007
$P^{\#}$	–		0.03		
	–		0.02		
			–	0.02	

SD, standard deviation.
MET, Metabolic Equivalent of Task.
School or work at 15 and associative activities after reaching normal retirement age.
**p < 0.05 between groups (light, moderate and vigorous work) and reference group (sedentary work).*
$^{\#}$*p < 0.05 between (i) ≥60-year-old group and <60, (ii) 60-79-year-old group and <60, and (iii) ≥80-year-old group and 60-79.*

age), compared with light (36%), moderate (16%) and vigorous (8%) intensity work, even more than 60 years ago (36% at 15 years of age). Hypertension was one of the most common risk factors, concerning 53.5% of the subjects and 203 (29.5%) had at least three CVD risk factors (**Table 1**).

The most active subjects at work were the most active outside the work: 8722 MET-min/week of moderate-to-vigorous physical activity (MVPA) on average at 60 years of age for subjects who had a vigorous intensity work vs. 4084 MET-min/week for a light intensity work *($p = 0.02$).* Difference of leisure time PA between an active work (light, moderate and vigorous intensity) and a sedentary work was significant ($p < 0.05$) (**Figure 2**).

Also, those who had a sedentary work remained sedentary at home: 4.5 h/d of sitting time on average at 60 years of age for sedentary workers vs. 3.3 h/d for very active workers ($p = 0.007$). In general, SBs increased with age ($p < 0.03$ between ≥ 60 and < 60-year-old subjects). Even retirees who had been active at work had significant greater sedentary time from 60 years of age ($p < 0.02$ compared with < 60-year-old subjects), and this was even more pronounced at age 80 ($p < 0.02$ between ≥ 80 and 60–79 year-old subjects) (**Figure 3**).

An active work (light, moderate or vigorous intensity) was associated with a 21% reduced risk of cardiovascular (myocardial infarction) and cerebrovascular events (stroke) (OR = 0.79 (0.32–0.91), $p < 0.02$) compared to sedentary work. This relationship was already and only significant for light intensity work (32%, i.e., OR = 0.68, 95% CI: 0.31–0.87, $p < 0.02$). Body

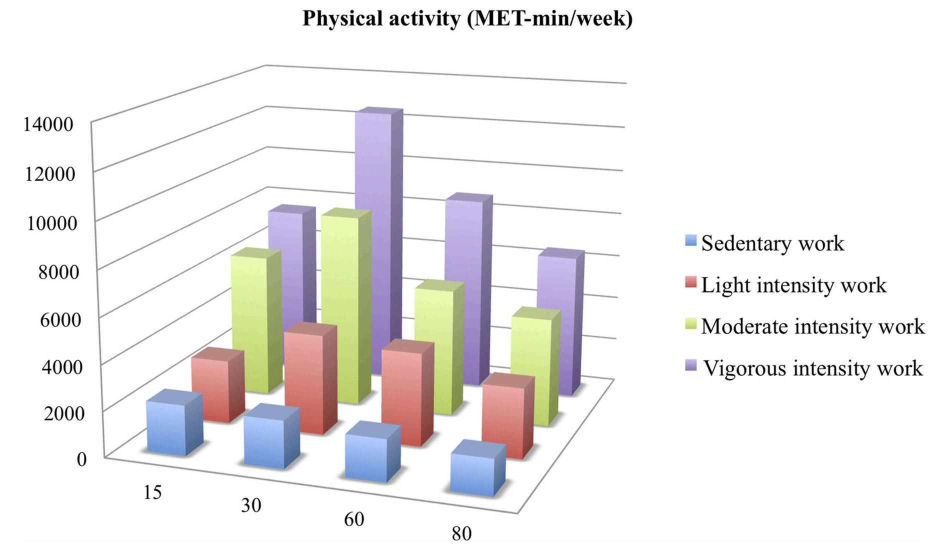

FIGURE 2 | Leisure time moderate-to-vigorous physical activity (MET-min/week) from 15 to 80 years of age according to activity or not at work. MET: Metabolic Equivalent of Task.

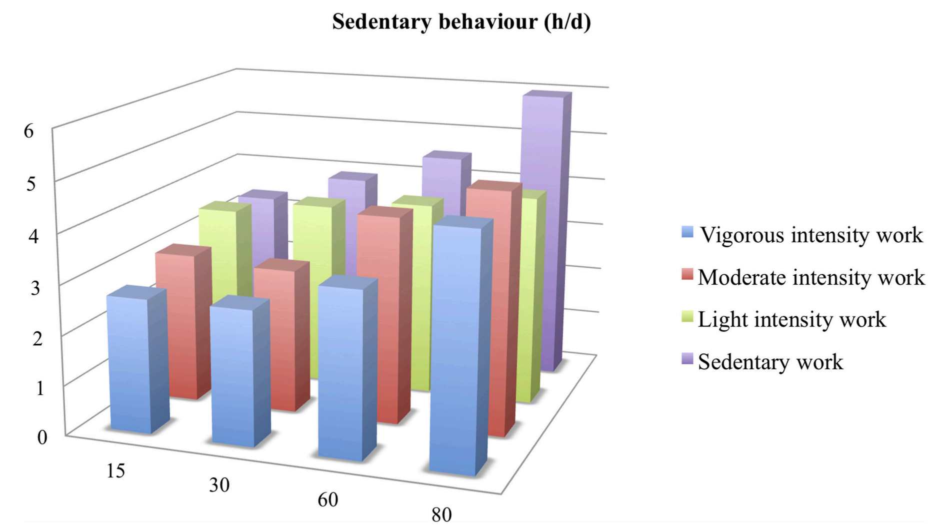

FIGURE 3 | Sedentary behavior (h/d) from 15 to 80 years of age according to activity or not at work. MET: Metabolic Equivalent of Task.

TABLE 2 | Sedentary behavior and physical activity at work: light (< 3 METs), moderate (3–5.9 METs), and vigorous (≥ 6 METs) intensity and adjusted cardiovascular and cerebrovascular events odds ratios (ORs 95% CI).

Variables	Total *N* at 65 = 1,011	Sedentary work	Light intensity work	Moderate intensity work	Vigorous intensity work
N at 80	688	275	248	110	55
Women *n (%)*	514 (75)	209 (76.0)	199 (80.2)	76 (69.1)	30 (54.5)
BMI, *mean (±SD) kg.m^{-2}*	25.0 (4.3)	25.4 (6.4)	24.9 (3.8)	24.8 (3.3)	23.8 (2.7)
BMI ≥ 25 kg.m^{-2} *n (%)*	205 (29.8)	85 (30.9)	67 (27.0)	37 (33.6)	16 (29.1)
Hypertension *n (%)*	368 (53.5)	164 (59.6)	114 (45.9)	60 (54.5)	30 (54.5)
Dyslipidemia *n (%)*	261 (38)	123 (44.7)	86 (34.7)	32(29.1)	20 (36.7)
Diabetes mellitus *n (%)*	83 (12.1)	32 (11.6)	28 (11.3)	14 (12.7)	9 (16.3)
Smoking *n (%)*	28 (4.0)	14 (5.1)	9 (3.6)	4 (3.6)	1 (1.8)
CVD risk factors ≥3, n (%)	203 (29.5)	92 (34.2)	62 (25.0)	32 (29.1)	17 (30.9)
CV events, *n (%)*	91 (9.0)	47 (17)	24 (10)	11 (10)	9 (16)
OR (95% CI) *Model A*		1	0.68 (0.31–0.87), $p < 0.02$*	–	–
			0.78 (0.37–0.90), $p < 0.02^{\#}$		
OR (95% CI)		1	–	–	–
Model B			0.79 (0.32–0.91), $p < 0.02^{\#}$		

BMI, body mass index: weight (kg)/height (m^2), $p > 0.05$ between groups.
SD, standard deviation.
Odds ratios (OR) for cardiovascular and cerebrovascular (CV) events (with 95% confidence interval) are adjusted for age and sex in Model A and for age, sex and CVD risk factors ≥3 in Model B.
$^*p < 0.05$ only between light intensity work and sedentary work (reference group, OR = 1).
$^{\#}p < 0.05$ between active group (light, moderate and vigorous work, n = 413) and sedentary work (reference group, n = 275).

mass index was not different between these four groups ($p > 0.05$) (**Table 2**).

Starting or resuming a moderate to vigorous aerobic PA during retirement was associated with a 49% reduced risk of myocardial infarction or stroke (OR = 0.51 (0.35–0.69), $p < 0.001$). Furthermore, any reduction, even when PA was initially low, exposed older adults to an almost 2-fold increased risk of cardiovascular and cerebrovascular events (OR = 2.06 (1.47–2.88), $p < 0.001$) (**Table 3**).

Reducing a SB during retirement was associated with a 30% reduced risk of myocardial infarction or stroke (OR = 0.70, 95% CI: 0.36–0.90, $p < 0.02$). Furthermore, any increase in SB, even when sedentary time was initially low, exposed older adults to an almost 1.5-fold increased risk of cardiovascular and cerebrovascular events (OR = 1.24, 95% CI: 1.11–2.82, $p < 0.02$), without difference in body mass index between both groups ($p > 0.05$) (**Table 4**).

DISCUSSION

Principle Findings

This study found that the risk of cardiovascular and cerebrovascular events in the PROOF cohort was related to their 15–60 years sedentary or active work as well as to their SB and leisure time PA during the 15 years of follow-up of our current cohort of 80-year-old subjects. Indeed, an individual's occupational activity may contribute significantly to daily PA and SB (13), even in retired people.

In this context, the risk for the onset of myocardial infarction and stroke was lower among those who had an active work compared to those with sedentary work. Even a light active work produced substantial health benefits, which is important since retired people tend to present with more sedentary and less active behaviors.

Interestingly, being sedentary at work was associated with more SB outside of work; while on the contrary, being active at work was associated with more leisure PA outside of work. Some studies already showed that sedentary workers were more likely to have high leisure time sitting. On the contrary to our study, some other studies showed that active work was associated with more sedentary leisure time (11, 20, 21). Hence, the relationship between PA at work and SB outside work is still unclear.

Moreover, we found that sedentary workers who reported the highest sitting time at work also reported the lowest leisure time PA. Thus, sedentary work was not compensated with less SB outside of work. Worse still, there would even be an accumulating sedentary effect of a physical inactivity. This finding is supported by some other studies with a similar focus (9, 11, 12, 20–24).

The decrease in PA and increase in SB with age observed after 60 years is in accordance with some previous studies in healthy

TABLE 3 | Cardiovascular end cerebrovascular events ORs (95% CI) according to changes of physical activity at the age of 65 years after 15 years of follow-up in the PROOF cohort study.

Variable	Total $N = 1{,}011$	Increase or maintenance of physical activity	Reduction of physical activity
Population (%)	688	354 (51%)	334 (49%)
Women *n (%)*	514 (75)	261 (73.7)	253 (75.7)
BMI, *mean (±SD) kg.m^{-2}*	25.0 (4.3)	24.9 (4.9)	24.8 (4.9)
BMI ≥25 kg.m^{-2} *n (%)*	205 (29.8)	97 (27.4)	108 (32.3)
Hypertension *n (%)*	368 (53.5)	160 (45.2)	208 (62.3)
Dyslipidemia *n (%)*	261 (38)	106 (29.9)	155 (46.4)
Diabetes mellitus *n (%)*	83 (12.1)	17 (4.8)	66 (19.7)
Smoking *n (%)*	28 (4.0)	16 (4.5)	12 (3.6)
CVD risk factors ≥3, *n* (%)	203 (29.5)	79 (22.3)	124 (37.1)
CV events (%)	91 (9.0)	32 (9.0)	59 (17.7)
OR (95% CI)		1	1.89 (1.2–2.98), $p < 0.01$
Model A		0.53 (0.34–0.83), $p < 0.01$	1
OR (95% CI)		1	2.06 (1.47–2.88), $p < 0.001$
Model B		0.51 (0.35–0.69), $p < 0.001$	1

BMI, body mass index: weight (kg)/height (m^2), $p > 0.05$ between groups.
SD, standard deviation.
Odds ratios (OR) for cardiovascular and cerebrovascular (CV) events (with 95% confidence interval) are adjusted for age and sex in Model A and for age, sex and CVD risk factors ≥3 in Model B.

subjects and can be explained both with the decrease in daily PA (20, 24). Retirement is an important turning point in life with many changes in daily routines. These results suggest that the lack of time outside the work period to practice PA is not a valuable excuse. This is important since we demonstrate, as others, that even after retirement, the decrease in PA and increase in SB may contribute to an increased risk of cardiovascular and cerebrovascular morbidity (12, 20). The explanatory variables for cardiovascular and cerebrovascular events (myocardial infarction or stroke) were gender, age (Model A in **Table 2**) and CVD risk factors ≥ 3 (including hypertension, dyslipidemia, diabetes, overweight, and smoking, Model B in **Table 2**).

We did not find a significant link between moderate or vigorous intensity at work and cardiovascular and cerebrovascular events, which is rather inexplicable because this relationship was present for light intensity work (ORs only adjusted with age and sex, *model A*). (i)This may be explained by the limited number of cardiovascular and cerebrovascular events in the cohort. (ii) Also, isolated CVD risk factors were not significant to explain cardiovascular and cerebrovascular events probably due to an age effect on these risk factors and probably due to their low prevalence in this relatively healthy population (smoking and diabetes mellitus). More probably, (iii) the explanation may lie in the J-shaped dose–response relationship between occupational PA and all-cause mortality, which have previously been reported for moderate-to-vigorous PA. Indeed, a very recent meta-analysis of 193,696 participants showed that men engaging in high (compared to low) level occupational PA have an 18% increased risk of all-cause mortality, even after adjustment for relevant confounders, such as leisure time PA (25). However, no dose-effect was identified in our study. It would seem that cardiovascular end cerebrovascular events might be more present in subjects from the cohort with at least 3 CVD risk factors.

Strengths and Limitations

The main strengths of our study include the PROOF cohort based design, with the long follow-up after retirement, allowing people to reach ages with a high morbidity-mortality rate, as well as the repeated measurements of PA and SB, and strong and complete information on morbidity-mortality (13).

However, there are some limitations to our study. This study relied on self-reported PA and SB (via modified GPAQ), which are subject to recall and information bias, especially for older people over the age of 80 in our study, possibly resulting in under-reporting of SB and over-reporting of PA. However, there is no reason to assume that these biases would be different for the different age periods and for the different work classes (26, 27). Also, simple questionnaires are well-suited for the study of changed behavior in large epidemiological studies (GPAQ) and the repetition of identical questions at each survey is one of the main strengths of our study (POPAQ).

The GPAQ is commonly used in Western and in low/middle income countries. According to the WHO, the GPAQ has been

TABLE 4 | Cardiovascular end cerebrovascular events ORs (95% CI) according to changes of sedentary behavior at the age of 65 years after 15 years of follow-up in the PROOF cohort study.

Variable	Total $N = 1{,}011$	Reduction or maintenance of sedentary behavior	Increase of sedentary behavior
Population (%)	688	299 (43%)	389 (57%)
BMI, *mean (±SD) kg.m^{-2}*	25.0 (4.3)	24.6 (5.1)	25.1 (4.9)
BMI ≥ 25 kg.m^{-2} *n (%)*	205 (29.8)	94 (31.4)	111 (28.5)
Hypertension *n (%)*	368 (53.5)	169 (56.5)	199 (51.1)
Dyslipidemia *n (%)*	261 (38)	126 (42.1)	135 (34.7)
Diabetes mellitus *n (%)*	83 (12.1)	34 (11.4)	49 (12.6)
Smoking *n (%)*	28 (4.0)	10 (3.3)	18 (4.6)
CVD risk factors ≥3, *n* (%)	203 (29.5)	88 (29.4)	115 (29.5)
CV events (%)	91 (9.0)	29 (9.7)	62 (15.9%)
OR (95% CI)		1	1.24 (1.11–2.82), $p < 0.02$
		0.70 (0.36–0.90), $p < 0.02$	1

BMI, body mass index; weight (kg)/height (m^2), $p > 0.05$ between groups.
Odds ratios (OR) for cardiovascular and cerebrovascular (CV) events (with 95% confidence interval) are adjusted for age and sex.

administered in more than 100 countries, initially developed for face-to-face interviews (www.who.int/chp/steps/GPAQ/en/index.html) (28). GPAQ was developed to combine the strengths of the short and the long International Physical Activity Questionnaire (IPAQ) but being considerably shorter (16 items) than the long IPAQ (27 items). It provided reproducible data and showed a moderate-strong positive correlation with IPAQ, the previously validated and accepted measure of PA (16, 17, 29). The French GPAQ format has been validated vs. actimetry (18, 30). There was a moderate/acceptable correlation for MVPA (spearman correlation, $r = 0.47$, from 0.45 to 0.63 in other study), often higher than reported in other studies (16, 17, 29). Correlation was low for sitting time, without difference with previous studies. The self-administered GPAQ has already studied (27, 31). Findings show that both interviewer- and self-administered modes of the GPAQ are comparable (16, 28).

However, accelerometers have limitations such that they do not measure water activities or cycling, so they may also underestimate MPVA (16, 18, 29, 31). Therefore, it may be relevant to use both a subjective and an objective measurement tool to obtain an assessment of PA type, intensity, duration, frequency and context. Measuring SB was difficult. Questionnaires explored a wide range of self-reported SBs during work and leisure. More accurate measurement might be provided by using an objective measurement tool that could distinguish between postures.

Implications for Policy and Practice

Epidemiological studies are a powerful tool for scientific societies to promote recommendations regarding PA intended for the general population. Based on our results, we propose to promote even a low intensity of PA at work, which corresponds in practice to advising sedentary people at work to get up regularly from the chair and walk a few minutes (to go down and to go up the stairs several times a day after a long sitting time, at the break or between two meetings) would be an already relevant advice (32–34).

Key Message

For the time being, it seems appropriate to recommend that even a low intensity active work should be encouraged as a means to reduce cardiovascular and cerebrovascular diseases. The positive correlation between physical activity at work and leisure time physical activity indicated that these two types of exercise may be a potential intervention to prevent myocardial infarction or stroke regardless of their activity intensity at work (35, 36).

We could say loud and clear that it is never too late to be physically active! It is not all over now! Our data may help to better identify target groups in public health interventions to specifically reduce SBs in retired adults. We should hearten everybody to aim at the current WHO recommendations through the whole spectrum of PA.

CONCLUSION

There is strong causal evidence linking both PA and SB at work and after retirement with cardiovascular or cerebrovascular disease. Even a light active work produced late substantial health benefits. Thus, the promotion of PA aims to lead retirees with an intention to change, to accompany them in this change, and to encourage them to maintain a more active lifestyle in the long term.

AUTHOR CONTRIBUTIONS

DH had full access to all data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. DH, FR, and J-CB had the idea for and designed the study. All authors had a substantial contribution to the conception and design. DH and JR conducted the literature search. DH, FR, and J-CB developed the study methodological design. DH, FR, and J-CB were responsible for collection and analysis of data. DH provided statistical expertise. DH, FR, and J-CB were responsible for interpretation of data, drafted the manuscript and submitted the paper for publication. DH, FR, JR, NB, MG, MB, KS, SC, VP, BB, and J-CB critically revised the manuscript for important intellectual content. All authors approved the final version.

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MINI REVIEW
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How to Measure Sedentary Behavior at Work?

Gil Boudet[1], Pierre Chausse[2], David Thivel[3,4], Sylvie Rousset[5], Martial Mermillod[4,6], Julien S. Baker[7], Lenise M. Parreira[1], Yolande Esquirol[8], Martine Duclos[9] and Frédéric Dutheil[10,11]*

[1] Faculté de Médecine, Institut de Médecine du Travail, Université Clermont-Auvergne, Clermont-Ferrand, France, [2] Cellule d'Accompagnement Technologique–Department of Technological Accompaniment, CNRS, LaPSCo, Université Clermont Auvergne, Clermont-Ferrand, France, [3] Laboratory of the Metabolic Adaptations to Exercise Under Physiological and Pathological Conditions (AME2P EA 3533), Université Clermont Auvergne, Clermont-Ferrand, France, [4] Institut Universitaire de France, Paris, France, [5] Unité de Nutrition Humaine, INRA, Université Clermont Auvergne, Clermont-Ferrand, France, [6] LPNC, CNRS, Université Grenoble Alpes, Université Savoie Mont Blanc, Grenoble, France, [7] School of Science and Sport, Institute of Clinical Exercise and Health Sciences, University of the West of Scotland, Hamilton, United Kingdom, [8] Occupational and Preventive Medicine, INSERM UMR-1027, Université Paul Sabatier Toulouse 3, CHU Toulouse, Toulouse, France, [9] Sport Medicine and Functional Explorations, CRNH, INRA UMR-1019, University Hospital of Clermont-Ferrand, Université Clermont Auvergne, CHU Clermont-Ferrand, Clermont-Ferrand, France, [10] LaPSCo, Physiological and Psychosocial Stress, Preventive and Occupational Medicine, CNRS, University Hospital of Clermont-Ferrand, Université Clermont Auvergne, CHU Clermont-Ferrand, WittyFit, Clermont-Ferrand, France, [11] Faculty of Health, School of Exercise Science, Australian Catholic University, Melbourne, VIC, Australia

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Edited by:
Daniel P. Bailey, University of Bedfordshire Bedford, United Kingdom

Reviewed by:
Anselm Ting Su, Universiti Malaysia Sarawak, Malaysia
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***Correspondence:**
Frédéric Dutheil
frederic.dutheil@uca.fr

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Background: Prolonged sedentary behavior (SB) is associated with increased risk for chronic conditions. A growing number of the workforce is employed in office setting with high occupational exposure to SB. There is a new focus in assessing, understanding and reducing SB in the workplace. There are many subjective (questionnaires) and objective methods (monitoring with wearable devices) available to determine SB. Therefore, we aimed to provide a global understanding on methods currently used for SB assessment at work.

Methods: We carried out a systematic review on methods to measure SB at work. Pubmed, Cochrane, Embase, and Web of Science were searched for peer-reviewed English-language articles published between 1st January 2000 and 17th March 2019.

Results: We included 154 articles: 89 were cross-sectional and 65 were longitudinal studies, for a total of 474,091 participants. SB was assessed by self-reported questionnaires in 91 studies, by wearables devices in also 91 studies, and simultaneously by a questionnaire and wearables devices in 30 studies. Among the 91 studies using wearable devices, 73 studies used only one device, 15 studies used several devices, and three studies used complex physiological systems. Studies exploring SB on a large sample used significantly more only questionnaires and/or one wearable device.

Conclusions: Available questionnaires are the most accessible method for studies on large population with a limited budget. For smaller groups, SB at work can be objectively measured with wearable devices (accelerometers, heart-rate monitors, pressure meters, goniometers, electromyography meters, gas-meters) and the results can be associated and compared with a subjective measure (questionnaire). The number of devices worn can increase the accuracy but make the analysis more complex and time consuming.

Keywords: occupational health, sedentary lifestyle, workplace, sedentary behavior measurement, work, questionnaires, wearable devices, recommendations

INTRODUCTION

Sedentary behavior (SB), has been defined as sitting or lying with low energy expenditure ≤1.5 METs (1) and is an independent risk factor for numerous adverse health outcomes. In industrialized modern societies, more and more time is spent for SB activities during normal lifestyle behavior, such as working on computers, traveling by car, and watching television during leisure time (2, 3). Further to this, more workers are now employed in low activity jobs such as administrative work. Office workers can have SB for more than ¾ of their working day (4). Chronic disease and all-cause mortality have been linked with self-reported time spent sitting (5–13). A dose response relationship has been demonstrated between all-cause mortality and daily total sitting, with a 2% increase in all-cause mortality per hour seated per day (14). Even after adjustment on the quantity of moderate or vigorous physical activity (15, 16), the risk of death persists, demonstrating that time spent sitting is a risk factor independent of the level of physical activity. SB can be measured by declarative methods (auto-administrate questionnaires) and objective methods (observation, video, or technical instruments). Descriptive parameters of physical activity and sedentary activity used most often are duration, frequency, intensity, domain or context (leisure, work, domestic, transport), and the type of activity. Indicators combining these parameters can be calculated globally or for each one of the domains individually. The most common are the volume (time × frequency) and the energy expenditure (duration × frequency × intensity), the latter being calculated to account for overall physical activity. Time spent in front of a screen (television, video, video games, computer...) is currently the most used sedentary indicator and in the majority studies, is the time spent watching television measured by survey techniques. Considering the public health impact of SB at work, there is now a growing research interest about sedentariness at work. However, SB is measured through a wide range of methods, but no scientific articles provide a global overview on all methods used to quantify sedentary behavior.

OBJECTIVE

The aim of this paper was to provide a global understanding on methods currently available for SB assessment at work.

SEARCH STRATEGY

Published studies with measures of SB at work were retrieved through a systematic search of the Pubmed, Cochrane, Embase, and Web of Science databases. We selected articles published between 1st January 2000 and 27th March 2019 because SB gained momentum in recent years, with more diversity on assessing SB at work, and because only recent articles distinguished between SB and physical inactivity and their specific health effects (6, 17–19). The search strategy and keywords used are detailed in **Supplementary Material Appendix 1**. We restricted our search to articles in humans and written in English. We did not restrict our search to specific countries or regions, nor on a minimal sample size. Included articles had to describe tools used to measure SB at work. The search strategy is displayed in **Figure 1**. Three authors (GB, PC, FD) conducted all literature searches and agreed on the final decision for articles inclusion. A fourth author (MD) reviewed articles when no consensus was met. Then, eligible articles were reviewed by all authors.

DATA EXTRACTION AND SYNTHESIS

We extracted the following information: type of study (longitudinal, cross-sectional), category of material (questionnaire, one common sensor, multiple sensors, complex physiological system), number of subjects and the main measure of sedentariness. Identified devices which assessed sedentary behavior at work where tabulated to highlight the performance and the usability of methods and devices to access sedentary behavior at work (see **Table S1** for the complete lists of included articles with those details).

CHARACTERISTICS OF INCLUDED ARTICLES

An initial search retrieved a possible 4,118 articles. Removing duplicates and applying the selection criteria decreased the number of articles reporting measures of SB at work to 154 articles (**Figure 1**). Among the 154 included articles, 89 were cross-sectional studies, and 65 were longitudinal studies, for a total of 474 091 participants. SB was assessed by self-reported questionnaires in 91 studies, and by wearables devices in also 91 studies. Among those studies, 30 studies used simultaneously a questionnaire and wearables devices. Among the 91 studies using wearable devices, 73 studies used only one device, 15 studies used several devices, and three studies used complex physiological systems. Studies exploring SB on a large population used significantly more only questionnaires and/or one wearable device. Complete list of included articles, with details on the type of the study, number of participants, type of measures of SB, and main outcomes are presented in **Table S1**. Methods of

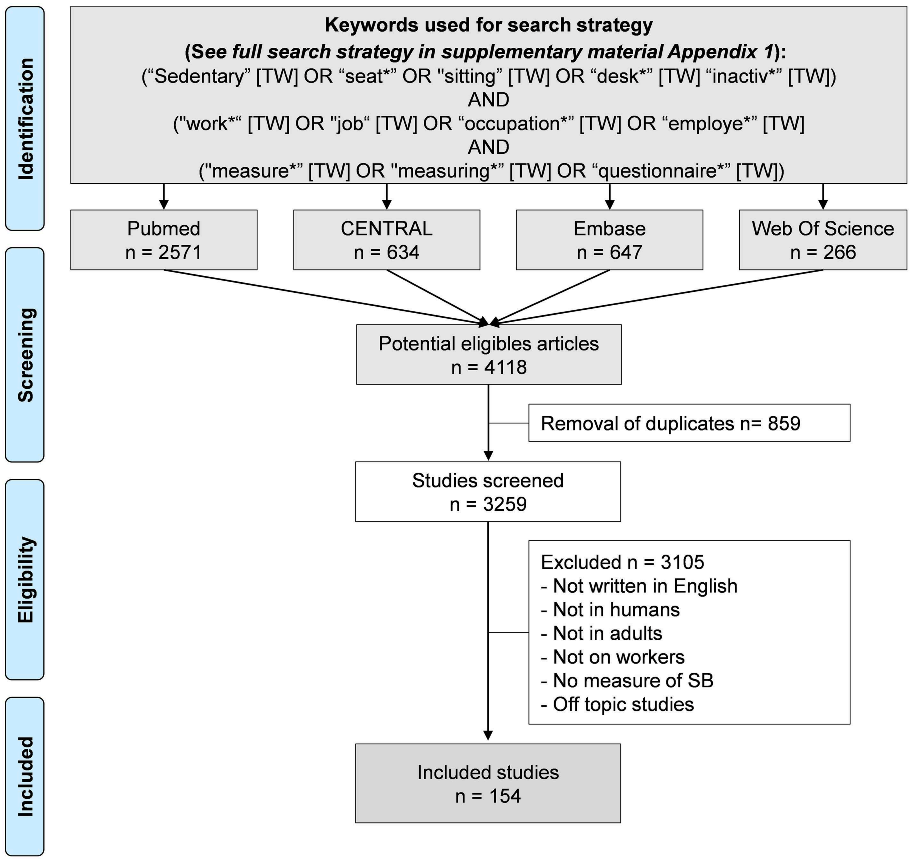

FIGURE 1 | Search strategy.

measuring SB retrieved in included articles are detailed below. For practitioners and researchers who want to evaluate SB at the workplace, we propose a strategy for the best options to evaluate SB in the workplace, depending on several factors, including comfort, number of subjects, duration of measures, accuracy, and budget (**Figures 2**, **3** and **Table 1**).

METHODS OF MEASURING SEDENTARY BEHAVIOR

Declarative Methods-Self-Reported Questionnaires

These questionnaires are the most common method of measuring SB, relying on recall ability of participants (20). The commonly used self-report questionnaires for SB at work assessment are: The Global Physical Activity Questionnaire (GPAQ), International Physical Activity Questionnaire (IPAQ) (21, 22), Workforce Sitting Questionnaire (WSQ, Adapted from the Marshall Questionnaire), Occupational Sitting and Physical Activity Questionnaire (OSPAQ) (23) and European Physical activity Questionnaire (EPAQ) (24). Questionnaires differed on global characteristics of SB or PA (such as duration, intensity or frequency), precision of data (habitual or recent, leisure, or non-leisure activities), reporting data (such as time, calories, or scores), time of recall (such as last week or over the 12 last months), and method for conducting the survey (such as paper, computer, face-to-face) (25). Questionnaires have the advantages of their low cost and low effort, both for responders and researchers, rendering them accessible for studies in large populations. However, self-reported SB at the workplace has been demonstrated to be imprecise, biased in measurement of light or moderate physical activity, and in the assessment of energy expenditure. Severe others limitations are the dependency on written language and external factors such as age, seasonal variation, complexity of the questionnaire, and social desirability) (26–30). Characteristics and performances of questionnaires for SB assessment at work are presented in **Table 2**.

OBJECTIVE METHODS

Visual Observation (Direct or Videotaped)

SB at work can also be assessed by visual observation, either recorded or on-site. Visual observation is still a classical method used by ergonomics, occupational physicians, or researchers (30). This method of assessment is often use for assessing body postures at work in delimited space (e.g., work space). Contextual information (such as location, clothing, or time) and details

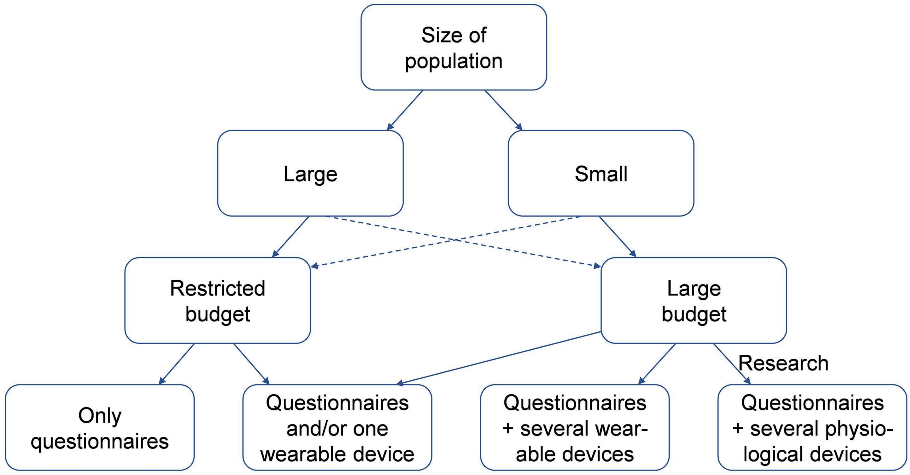

FIGURE 2 | Decision strategy for the best option to measure sedentary behavior at work.

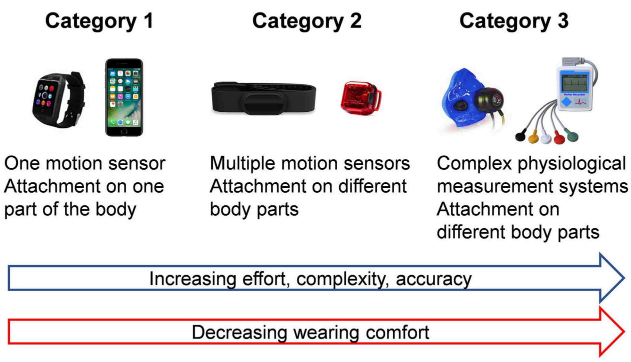

FIGURE 3 | Categorization of wearable devices to measure sedentary behavior depending on accuracy and complexity.

on SB (such as type or personal activities) could be assessed with this method. However, direct observations are costly and time consuming (31), and are therefore mostly adapted for small populations and on short periods. Visual observations are also dependent on observers who may rate differently the same behavior (32). Observed workers may also modify their behavior (observational bias) because of the logistic burden associated with data collection. Videotaped monitoring at work also needs the authorization of the employers and workers and ethical consideration.

CARDIORESPIRATORY ASSESSMENT

Indirect Calorimetry (IC)

With IC, total energy expenditure is calculated from Weir's formula that takes into account oxygen consumption and carbon dioxide production (33). This accurate and non-invasive method can be used in routine but not in large epidemiological studies nor for measures in an ecologic environment (outside of a laboratory or a specific workplace setting). Moreover, materials needed are costly. For data collection, the workers needs to wear a facemask linked with a central unit. For ambulatory measurements, the central unit could be worn in a backpack. Thus by discriminating energy expenditure, SB is defined as seated, reclining, or lying activities requiring low levels of energy expenditure (i.e., $\leq$1.5 METs), light-intensity physical activity (LPA) as standing is between 1.6 and 2.9 METs and Moderate-to vigorous-intensity physical activity (MVPA) require energy expenditure $\geq$3.0 METs). IC can evaluate sedentary time. These analyzers are now portable like the Cosmed K5 (34) or Metamax Cortex (35). Their use over a long period can be difficult to support depending on the activity of the worker but are still feasible. Because of the relatively slight differences in energy expenditure between sitting and standing posture (36, 37), assessment of energy expenditure does not provide reliable information about the body posture. So, measurement of body posture is also required for assessment of SB at work. Conversely, most of body positions at work can be assessed by wearable devices. The use of multiple devices may also inform on anatomical location of movements.

Holter-Electrocardiography (Holter-ECG)

A linear relationship between cardiorespiratory response and energy expenditure, and thus with activity intensity has been clearly demonstrated (38). Heart rate (HR) can therefore be used to estimate energy expenditure. Coupling HR monitoring and accelerometers leads to a better accuracy in the assessment of SB and physical activity (30, 39). Historically, electrical HR sensors detect the electric impulses that are linked with the myocardial contraction. The signal allows detection of all heartbeats, and therefore of the HR. In clinical setting, the gold-standard for electrocardiographic assessment is a 12-lead ECG. In an ecologic environment (outside of hospital), a portable 3 or 5-lead Holter-ECG is commonly used for scientific research. It allows abnormal heart rhythms and cardiac symptoms detection and is considered

TABLE 1 | Instrument, raw unit, cost, and environment of tools to measure sedentary behavior at work.

Instrument	Measure/raw unit	Cost	Environment
Questionnaire	Response quote qualitative	Negligible	Possible at work but take time
Video observation	Video qualitative	50 to 500€ for a camera	May need authorization especially at work
Smartphone	All sensors (XYZ g, m/s, position, direction, brightness illuminance lux …)	300 to 1000€ + costs of applications	Easy to wear and common
Accelerometer	g or count (on X,Y,Z axis 3D, position, direction, brightness illuminance lux)	50 to 400€	Easy to wear even at work
Heart rate monitor	Beat/minute	50 to 300€	Easy to wear even at work
Holter-ECG	RR interval from ECG	300 to 2000€	Easy to wear even at work
Gas analyser	O2 CO2 consumption/production (liter, m^3…)	20 to 30000€	For a short period on few individuals Less comfortable

as a medical device. Commercially wearables Holter-ECG are often based on simply a 1- or 2-lead ECG. Despite its accuracy and validity, measures with 1- or 2-lead Holter-ECG are more susceptible to artifacts because of external factors, and therefore are not consider as a medical device. Major causes are motion, physical and muscle activity, or detachment of electrodes (40, 41). To allow better diagnostic accuracy, the worker can place time markers for specific activities or events at the workplace. Data can be stored directly into a specific memory into the device or in a digital storage media (e.g., SD cards). Data are downloaded and analyzed with specific softwares by a cardiologist, a physician, or a researcher.

Heart-Rate Monitors

There are two different types of technology used by HR monitors: the electrical signal (chest belt) and optical sensor (wristwatch or armband) (42). Chest belts detect electrical signals sent through the heart each time it contracts (ECG-based detection of RR interval). Sometimes, chest belts can transmit HR data on a wristwatch providing a feedback (pulse monitoring) to the user. The Optical HR measurement is based on photoplethysmography (PPG). The Optical HR devices use integrated LED and light sensors to detect HR through rhythmic changes in blood flow occurring at each systole (blood volume pulse) (43). These sensors are cheap, discrete, and comfortable. They are mostly placed on wrists and arms, and sometimes ear lobes or fingertips. Main limitations are artifacts because of motion and a decreased sensitivity with some skin texture (44). ECG-based chest belts still offer the most reliable, consistent, and accurate way to monitor HR thanks to higher sampling rates and the position of the electrodes closer to the heart (45). However, many people prefer the comfort and convenience of optical sensors built into watches, such as Applewatch. HR monitors are able to capture energy expenditure during working activities and to categorize levels of physical activity. Moreover, they can estimate the energy expenditure even with no vertical trunk displacement that is not taking into account by most accelerometers and pedometers (46). HR monitors are less accurate to estimate energy expenditure particularly at very high and low intensities (47), because the relationship between HR and energy expenditure is not linear for high intensity of physical activity or at rest and low-intensity (with confounding factors such as body position, stress, or caffeine affecting the HR—energy expenditure relationship) (47). Others factors also affect this linear relationship or reduce its accuracy, such as age, sex, body composition and muscle mass, or fitness level (48).

Accelerometers

Accelerometers are currently used to measure and quantify the physical activity intensity category related to SB and have become the method of choice for measuring SB. Accelerometers are easy to use, accurate, and able to capture large amounts of data, particularly in large studies. These devices detect movement in real time and measure acceleration (counts) in three orthogonal planes (anteroposterior, mediolateral, and vertical) (49). The postulate is that the acceleration detected is proportional to the force produced by the muscles engaged in motion, and therefore related to energy expenditure. Time of SB is assessed by two different ways to detect body posture (standing, sitting, or lying): (1) posture by tri-axial sensors using gravitational components, or (2) spinal curvature by three uni-axial gyroscopes orthogonally aligned. Some accelerometers fail to differentiate walking intensity or body position (such as standing or sitting) (50). New accelerometers have a better validity than older models, compared to energy expenditure measured by doubly labeled water (DLW). However, accelerometers cannot provide contextual information (such as type of activity and setting) and induce a reactivity bias (51). Accuracy to determine SB depends on the threshold chosen for each count (count cut-point) (52). Most of the time, the acceleration counts characterize sedentary (absence of movement) and active behavior. The most commonly used cut-points for adult populations are <100 counts/min for SB, 100–1,951 counts/min for light-intensity physical activity (LPA), and ≥1,952 counts/min for moderate-to vigorous-intensity physical activity (MVPA) for the ActiGraph accelerometer (53, 54). However, these cut-points were developed in specific populations and during strict, laboratory-based protocols. Other studies validating the ActiGraph have found vastly different cut-points for SB (range 50–250 counts/min) and MVPA (191–2,691 counts/min) in adults, depending on the population and type of validation setting (55, 56). The cut-point method has several limitations; it cannot differentiate standing from sitting/lying, but standing is considered LPA because it

TABLE 2 | Characteristics of self-report questionnaires to measure sedentary behavior at work.

Measure	Period(s) of interest	Categories of activity included	Input	Output	Special notes
GPAQ	Typical week	16 items; PA at work, Moderate to vigorous, Transportation, Leisure-time	MET-min per week	Time spend in moderate or vigorous PA, Job-related PA, Total physical activity, Time spend sitting	For adults of both sex. For face-to-face interviews conducted by trained interviewers. Many domains explored. Quantifies exposure. Cross cultural application. 20 min.
IPAQ-S (short)	Past week	7 items; moderate or vigorous PA, walking, sitting, including time spend at work	Duration (min per week)	Duration in each PA domain and sitting, Job-related	For adults of both sex. Self-administered. Many settings and in different languages. Cross cultural application. Shorter than IPAQ-S. 10 min.
IPAQ-L (Long)	Past week	24 items; moderate or vigorous PA, walking, sitting, including Job-related PA, house work, transportation PA, and weekend	Duration (min per week)	Duration in each PA domain and sitting, Job-related, house work, leisure	For adults of both sex. Self-administered. Many settings and in different languages. Cross cultural application. 30 min.
WSQ (Workforce Sitting Questionnaire)	Past week	Duration of work. Total and domain-specific sitting time based on work and non-workdays, transportation. Time spend watching TV, computer, others leisure	Duration (min per week)	Duration of work. Time spend sitting at work and in non-workdays. Time spend in transportation, in screen watching and other leisure	For adults of both sex. Self-administered. For measuring sitting time at work on a work-day and for assessing total sitting time based on work and non-workdays. Cross cultural application.
OSPAQ	Past five working days	7 items; Work time spent sitting, standing, walking, and doing heavy labor, as well as the total length of time worked in the past five working days	Duration (min per week)	Time spend sitting, standing and walking, and doing heavy labor and total length of working	For adults of both sex. Self-administered. Only Job-related PA, excluding transportation, and leisure time. 10 min.
EPAQ	Typical week	21 items; Sitting and standing, moderate PA in leisure and working time, heavy labor at work	Duration (min per week)	Time spend standing, sitting, doing moderate PA at work and in non-workdays, in house work, and leisure and heavy labor at work	For adults of both sex. Self-administered. Do not distinguish moderate and vigorous PA, but focus on moderate PA. Assessed walking and bicycle separately.

MET, Metabolic equivalent of task (1 MET represents 3.5 ml/kg/min oxygen consumption); PA, Physical Activity; Questionnaires, GPAQ Global activity Questionnaire, IPAQ International Physical Activity Questionnaire, IPAQ-S (Short version), IPAQ-L (Long version), WSQ (Workforce Sitting Questionnaire), EPAQ (European Physical Activity Questionnaire).

elicits different physiologic responses and has different long-term health consequences than sitting/lying (57, 58). Thus, the interpretation of what is considered to be active behavior is consequently different and makes the comparison between the studies difficult. Obese people spend more time in SB than normal weight individuals (59, 60). Thus, cut-points have to be more accurate to show difference among and between normal-weight and obese populations. Accelerometers worn on the right thigh achieve high accuracy for classification of three distinct physical activity intensity categories (SB, LPA, and MVPA) as well as breaks in SB in a semi-structured setting. Wrist accelerometers also have high accuracy for assessment of SB but have some misclassifications of LPA and MVPA, with interestingly better accuracy when they are worn on the left wrist compared to the right wrist (or hip). These findings support the use of accelerometers worn at the thigh to assess the time spent in SB and different categories of physical activity intensity. Alternately, for researchers using wrist-worn accelerometers to assess physical activity, wear on the non-dominant wrist is likely to allow for higher measurement accuracy than wear on the dominant wrist (61). Due to limitations of the cut-point approach to measure categories of physical activity intensity, researchers have utilized modelization technics to improve accuracy of physical activity measurement from accelerometers worn on various body locations (62, 63). An accelerometer does not give the position information of the subject. It will be completed by a gyroscope (measuring orientation and angular velocity) (Samsung Gear S3) and a magnetometer (detecting Erath's magnetic three perpendicular axes X, Y, Z) (Actigraph GT9X) (64). The ActivPal is an alternative tri-axial accelerometer thigh-worn. The thigh position allows the determination of step counts, stepping speed, and start-end of each period spent sitting, lying, standing, or stepping, as well as breaks in SB and postural transitions. The ActivPAL is a monobloc system that is discrete, easily used by individuals, without calibration, and reliable for the measurement of SB (65, 66). Therefore, ActivPAL is increasingly used in ecological environment outside laboratories.

Global Positioning System (GPS)

Global Positioning System (GPS) can complete this variety of sensors by giving the geographical position (latitude and longitude) and time of each geographical position, but mainly outside building. Newer GPS can also deliver information such as speed (retrieved from time between different geographical positions), elevation, and indoor/outdoor activities. However, most workers spend a high proportion of their time indoors, and unfortunately GPS are only able to receive indoor signal from small buildings with a wooden roof or high buildings with large windows. GPS are unable to determine room-level of indoor location (67). However, even if GPS is mostly for outdoor activities, newest GPS can also track SB indoors. Moreover, some devices also include useful tools such as a brightness sensor to access sleep quality. These wearable lightweight GPS devices are easily forgotten by users. The researcher should take care to check the sampling frequency, resolution, and the maximum amplitude of the device. In order to make long observations, it is also necessary to check the device battery and storage space. Recent smart-phones or smartwatches are equipped with all the mentioned sensors.

Smartwatches and Smartphones

Smartwatches are wrist-worn computerized devices with extensive communication capabilities. They are linked to one mobile operating system. In perpetual development, manufacturers continue to implement new features, such as GPS, fitness/health tracking, or waterproof frames (16). The gestures of the hands, such as smoking, are now accessible thanks to the addition of reliable and sensitive inertial sensors (17). In a recent meta-analysis (68) the most popular smartwatches (connected devices) on the market were compared: from Apple, Fitbit, Garmin, Lumo, Misfit, Samsung Gear, and TomTom. Generally, smartwatches tend to underestimate energy expenditure compared to laboratory reference measurements (Oxycon Mobile, CosMed K4b2, or MetaMax 3B). Moreover, while smartwatches get better to estimate energy expenditure with an increased intensity, validity becomes poorer with low intensity, and sedentary measures. Because everyone has a smartphone, they are an alternative to smartwatches or other wearable devices. Now, all smartphones combine many sensors, such as GPS or Global Navigation Satellite System (GLONASS), accelerometer, e-compass, gyroscope, proximity sensor, or ambient light sensor. Conveniently, smartphones can be linked with an HR belt, a smartwatch, or even a gas analyzer. However, all wrist and forearm devices have a tendency for underestimating HR, especially for exercises at high intensity and with amplitude of arm movement (such as exercising on a treadmill or an elliptical machine)—and conversely, measures of HR are more accurate at rest or for exercise without movement of arms (such as on a cycle ergometer). While HR is underestimated for high intensity of physical activity, step count on the opposite is underestimated for slower walking speeds and in free-living conditions. Smartphones are also particularly attractive for context awareness and phone-based personal information (69). The recognition of some activities are dependent on position-attachment of the phone on the body (70). For example, to recognize a specific activity, the smartphone should be placed on the major members involved within the activity. Unfortunately, a smartphone placed onto the body can also be non-compatible with some activities in an ecological environment (free-living conditions). Algorithm used for long recording periods can quickly consume the battery power, and may need a power supply. Another point consists of choosing the accurate available application.

Mobile Applications

Smartphone applications experienced a boom in medical science. In 2016, the Play Store displayed 105,000 and the Apple Store 126,000 health or fitness-related apps (71). These applications propose physical exercises and fitness programs with or without connected objects such as wristband, pedometer, scale, HR monitor, smartphone, and smartwatch. When the mobile applications integrate the use of sensors (accelerometer, HR monitor, GPS), they inform the user of steps, distance, energy expenditure, speed, and heart frequency. The three most popular applications are Fitbit, Noom, and AppleHealth (**Table 3**). These special features are welcomed by the users. Conversely, most of the applications are not scientifically validated.

WellBeNet (eMouve) and IntellilifePro were two applications recently scientifically validated to assess accurately time spent in SB, LPA, MVPA, and the total energy expenditure associated. These two applications were specially developed to discriminate SB from LPA, such as standing or slow walking. Accelerometry data are collected via smartphones [WellBeNet (eMouve)] or via both a smartphone and smartwatch (IntellilifePro).

E-Move

E-move (Android) application detects leg movements as the smartphone is worn in a front pants pocket. Different algorithms were designed for normal and overweight/obese adults. The total energy expenditure and time spent for each category of physical activity given by the E-Mouve algorithms were compared with reference method or device: either Armband or indirect calorimetry (FitmatePro, Cosmed). Absolute error of the total energy expenditure and activity estimates are 5.6 and 5.0%, respectively in normal weight volunteers, and 8.6 and 5.0% in overweight/obese participants (72, 73).

TABLE 3 | Characteristics and physical activity parameters evaluated by the three most downloaded mobile applications.

Application	Operating system	Wearable monitor	Measured parameters
Fitbit	Android iOS Web	Accelerometer (wristband) Manual input	Number of steps or stairs Intensity Distance Calories burnt
Noom	Android iOS	Smartphone sensors GPS HR monitor	Distance Calories burnt Speed
Apple iHealth	iOS	RunKeeper (GPS) Moves (GPS and smartphone sensors) Manual input	Distance Calories burnt Number of steps Duration of activities

IntellilifePro

IntellifePro is based on the simultaneous use of a smartphone and a smartwatch (Android or Apple) to detect both leg and wrist movements. IntellifePro can discriminate passive from active sitting when in a sitting posture, while the arm, the wrist and/or the hand are engaged in the movement. Absolute error of the total energy expenditure and activity estimates are 3.1, 2.8, 1.5, and 0.04%, for SB, light, moderate, and vigorous intensity, respectively. The absolute error for total energy expenditure was lower than 5% in free living conditions (74).

Pressure Sensors

Another alternative to assess SB is via pressure sensors. Sensors can be placed in a sock, a shoe, or a chair. In a sock or shoe, a high pressure measured by the sensor is related to standing, and a low pressure is related to sitting or lying. On a chair, pressure sensors (sitting pad) are generally binary: active when the user is sitting, and inactive when nobody is sitting on the sensor (75). Current technologies and attachment on the body are presented in **Figure 4**.

Characteristics of Sedentary Behavior

Total daily duration of SB is commonly used to study the effects on health of SB. However, characteristics of SB are of major importance on health. Particularly, continuous prolonged

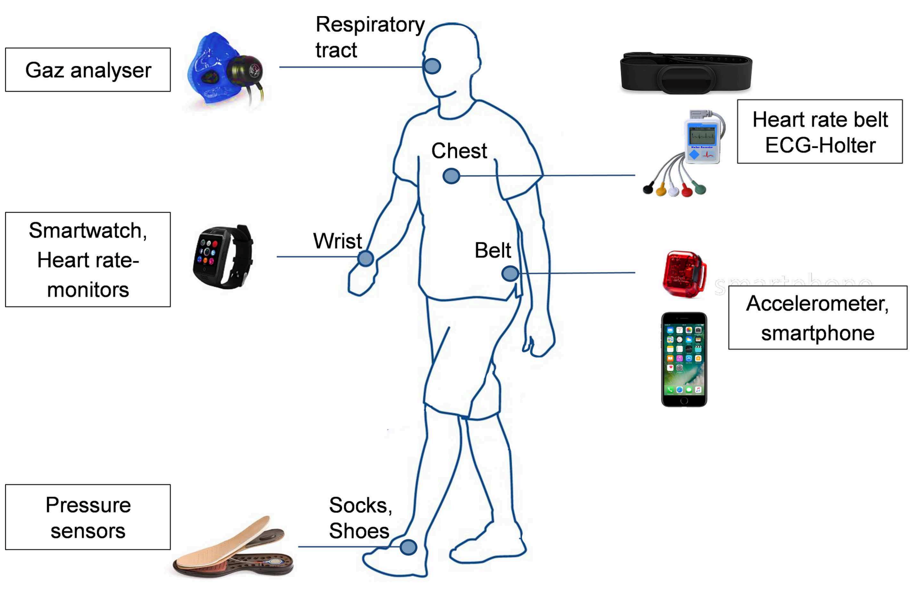

FIGURE 4 | Current technologies to measure sedentary behavior and attachment on the body.

SB may be more deleterious on health outcomes than shorter bouts of SB but with the same duration (76, 77). The need for a definition of a sedentariness has also been proposed (78). Investigations of SB at work should not only assess total daily duration of SB, but also the patterns and durations of SB and non-SB periods. The context of SB is also important (what, where, why, when, and with whom).

Limitations

Smart clothing (such as shirts with sensors measuring HR, socks or shoes combining pressure and accelerometers, or helmets and caps with a camera and GPS), goniometers (measuring an angle and angular position), electromyography meters (measuring the electrical activities of muscles EMG), and wearable camera have been voluntary excluded of the presented devices because still in development and not yet used to assess SB at work.

CONCLUSION

We proposed a systematic review on tools available to measure SB at work. SB was mainly assessed by self-reported questionnaires or by only one wearable device. Studies using several devices were less common, and rarely studies used complex physiological systems. The wide range of wearable devices offer a variety of methods to evaluate SB at work. It is not an easy task to select the optimal device and the right measurement strategy for a particular study purpose. The main factors of work (inside or outside, working movements, and postures) and study population (i.e., number, age, gender, body mass index, and comorbidities) may also affect the choice. To assess SB at work, four determinants factors should be considered to choose the appropriate method: (1) quality of measure (e.g., time spent on SB or energy expenditure), (2) objectivity of the data and burden of workers (e.g., time/effort for measures), (3) cost/burden for the researcher, and (4) specific limitations due to environment and working activities. Available questionnaires are the most accessible method for a large population with a limited budget. SB at work (time sitting) is accessible from some specific items. It is also possible to deduct SB in measuring PA at work that is easily measurable. Assessments of SB need both measures of energy expenditure and of body posture (dual or multiple wearable devices with sensors). Accurate measure of SB at work need a sufficient number of subjects affected to the same assigned task and an objective measure coupled to a questionnaire (mixed approach method). For a restrictive group, SB at work can be objectively measured with wearable devices (accelerometers, heart-rate monitors, pressure meters, goniometers, electromyography meters, gas-meters) and can be associated with subjective measures (questionnaires). The number of devices worn increase the accuracy but make the analysis complex and time consuming. Furthers studies are necessary to improve the relative strengths and weakness of subjective or objective methods to assess SB at work.

AUTHOR CONTRIBUTIONS

FD conceived the article. GB, PC, DT, MD, and FD contributed to drafting the article. All authors performed critical revision of the article.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2019.00167/full#supplementary-material

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The Perceived Value of Reducing Sedentary Behavior in the Truck Driving Population

Sarah L. Mullane [1]*, *Douglas Connolly* [2] *and Matthew P. Buman* [1]

[1] *School of Nutrition and Health Promotion, Arizona State University, Phoenix, AZ, United States,* [2] *Stewart Transport, Phoenix, AZ, United States*

Purpose: To conduct rapid qualitative analysis early in the intervention design process to establish the perceived value of reducing sedentary behavior in the truck driver population.

Methods: A rapid assessment process for qualitative data collection was used to examine managerial and employee perceptions quickly and iteratively to inform intervention design. Managerial insights were collected during semi-structured interviews and employee insights were collected via an online survey and focus group. Thematic analyses were guided by the constructs of the Health Belief Model to establish; (a) perceived susceptibility to the health problem; (b) perceived severity of the health problem; (c) perceived benefits of the potential solutions; (d) perceived barriers to adopting the recommended solution; (e) cues to action; and (f) self-efficacy.

Results: Three managers (2 females; 1 male) participated in semi-structured interviews. Seven truck drivers (1 female; 6 males) took part in a focus group. Sixteen survey responses (all male, mean age 49.8 ± 12.4 years, 86% white Caucasian) were collected in total (11 paper based; 6 online). The most important managerial motivators for engagement in an intervention included; improved sleep, alertness and quality of life. The most important employee motivators included; stress reduction (3.3 ± 1.3), improved quality of life (3.3 ± 1.3) and alertness (3.2 ± 1.4). Managerial and employee perspectives indicated that sedentary behavior may be of lower priority than diet and exercise, and may not resonate with the truck driving population as a health risk.

Conclusion: Application of the Health Belief Model indicated a disconnect between the researcher, managerial and employee perspective and the perceived value of a sedentary behavior reduction intervention. Within the truck driving population, researchers should endeavor to include safety as well as health outcomes, use multi-level strategies, design for outcomes of high perceived value and leverage health communication strategies to communicate benefits that resonate with the end-user.

Keywords: truck drivers, sedentary behavior, perceived value, Health Belief Model, engagement

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Melanie M. Adams,
Keene State College, United States
Yuke Tien Fong,
Singapore General Hospital, Singapore

***Correspondence:**
Sarah L. Mullane
slmullan@asu.edu

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INTRODUCTION

Truck drivers are classified as one of the highest-risk occupational segments due to a complex interplay of health behavior barriers across the socioecological spectrum (1). In the commercial driving population, rates of obesity have been reported to be as high as 50%, while the prevalence of diabetes is 50% higher than the general population (2). Contributory factors include occupational influences on diet, exercise, sleep and more recently sedentary behaviors (1). Detrimental associations have been observed between prolonged sedentary time [any waking behavior in a seated or reclining posture with low energy expenditure (<1.5 metabolic equivalents [METS])] (3) and BMI (4), waist circumference and 2-hr plasma glucose (5). Bouts of standing (6–8), light-intensity physical activity (LPA) (7, 9–11) or non-exercise activity thermogenesis (NEAT) (12) may attenuate these effects. Despite a recent shift toward environmental changes (sit-stand/active workstations) in office-based work environment (13–15), further challenges exist in non-office environments where prolonged sitting is prevalent (e.g., occupational driver settings). Existing environmental, cultural and social solutions for sedentary office workers do not translate to this challenging setting and evidence on how to intervene is extremely limited (16).

Health promotion efforts within the truck driving population have primarily focused on exercise and/or diet based interventions (17). However, low engagement or high attrition rates are typically reported, which has led to concerns regarding sustainability and impact (18). Lack of engagement may be further amplified when targeting sedentary behavior reduction for two reasons. Firstly, the basic premise in ecological models of health behavior is that efforts to change individuals' behavior cannot be effective if environments make it difficult (19). As standing and moving is not conducive to occupational driving, it is likely the barriers are even higher than those associated with diet and exercise interventions. Secondly, health-related risk perceptions play an important role in motivating health behavior change (20). Although individual level factors such as family history may influence perceived susceptibility to disease, risk perceptions are often influenced by the frequency with which a threat is represented in media exposure (21). As an emerging health risk factor, which may not have substantive evidence and/or consistent media exposure, sedentary behavior may not be considered to be a "real" or high priority risk factor within the trucking population.

The Health Belief Model is a Cognitive Value-Expectancy Theory which emphasizes the perceived value of the outcome, and the subjective expectation that a behavior will result in the outcome (22). A person must feel personally susceptible to a disease with serious or severe consequences and must believe that the benefits of taking the preventive action outweigh the perceived barriers to (and/or costs of) preventive action, in order to adopt a recommended preventive health action. Personal values must be considered along with factual evidence of treatment efficacy in order to facilitate health promotion "*by the person.*" Determining how to intervene is contingent on the perceived susceptibility and perceived value of an intervention.

In an effort to address the disparate health risks of the truck driver population and to inform the development of interventions specifically targeting sedentary behavior, we seek to understand the perception of sedentary behavior in the truck driving population. The purpose of this research within the truck driving community was to examine the perceptions of sitting as a health risk factor. We have used the Health Belief Model as a guiding framework, including the barriers, motivators, the perceived value of and receptivity to potential health interventions, that may target sedentary behavior in the truck driving population.

METHODS

A rapid assessment process for qualitative data collection was used to develop a preliminary understanding of a situation from the insider's perspective quickly and iteratively to inform intervention design (23). Using a mixed-methods approach, formative research was conducted with a local Phoenix based truck company to retrospectively examine attitudes toward sedentary behaviors at work and the perceived opportunity for intervention (including barriers and motivators). An in-person, semi-structured interview (which allowed for expansion) was conducted by SM with managers of the trucking company to gather managerial insights. Employee insights were collected during an onsite visit to a driver training day which facilitated a focus group with active truck drivers. Due to the rapid assessment process and early stage of the partnership, detailed notes (rather than audio) were recorded (23). Finally, further employee insights were collected via a survey which could be completed online (via Qualtrics) or using a paper based version that was distributed in-person to truck drivers as they visited the headquarters. All responses were de-identified as soon as the response was recorded and a $10 gift card incentive delivered to each participant. In addition to demographic information, respondents were asked a series of 5-point Likert scale questions (not at all [1] to extremely [5]) to rate; (a) the likelihood of engaging in behaviors to reduce sitting; (b) the motivators for participating in an intervention to reduce sitting; and (c) the perceived value of supporting tools or mechanisms to increase engagement. This study was approved by the Arizona State University Institutional Review Board. All participants consented using an online or paper based consent form.

Analyses

A thematic analysis of the key requirements and points raised during the semi-structured interviews and focus group was conducted. All closed survey question responses were imported and analyzed using SAS Enterprise Guide 7.1. All open ended questions were reviewed individually and word repetition used to identify the most prominent barriers and motivators (24). Findings were summarized using the constructs of the Health Belief Model (22) which included; (a) perceived susceptibility to the health problem; (b) perceived severity of the health problem; (c) perceived benefits of the potential solutions; (d) perceived barriers to adopting the recommended solution; (e) cues to action; and (f) self-efficacy.

RESULTS

Three managers (2 females; 1 male) participated in semi-structured interviews. Seven truck drivers (1 female; 6 males) attended the driver training day and took part in a focus group. Sixteen survey responses were collected in total (11 paper based; 6 online), five of which were responses from those who also participated in the focus group. Of those that completed the survey, all were male, mean age 49.8 ± 12.4years and 86% white Caucasian. All survey and semi-structured interview findings are summarized in **Table 1**. Specific survey results pertaining to motivators for engagement, the likelihood of engaging in preventative behaviors and receptivity to suggested health solutions are presented in **Figures 1–3**, respectively.

Manager Perspective

The results presented in **Table 1** (employer perspective) indicated that managers acknowledged high susceptibility to diabetes and overall increased cardiovascular disease (CVD) risk in the truck driver population compared to the general population. However, they did not necessarily attribute this risk to prolonged sitting but instead a combination of poor diet and lack of exercise due to being "on the road." Perceived severity was considered high due to their concern regarding the cyclical relationship between poor health, poor sleep and alertness and potential impact on driver safety. Perceived benefits were consistently related to driver safety by potentially improving sleep, alertness, well-being and quality of life. A notable managerial perceived benefit included the ability to change the public perception of the profession as being detrimental to health, which may facilitate future recruitment efforts. Perceived barriers included the potential for driver distraction that may arise via digital solutions and existing policies which dictated work breaks and time on the road. Additional concerns were raised regarding the isolated nature of driving and being able to distribute change across the organization with limited group based contact. Finally, concerns were also raised regarding the disconnect between research and the real world and the extent to which the driving culture may override researcher efforts.

Managerial cues to action included an intervention designed to monitor sleep and alertness, in addition to glucose control. Rest area redesign, signage and coaching were identified as being desirable components of the health solution. Digital solutions were only deemed appealing if they targeted rest areas, breaks and out of work hours (i.e., not while driving). Overall perceived self-efficacy of being able to reduce prolonged sitting and increase levels of activity during the work day was low given the nature of the job. However, targeting outside work hours was considered much more feasible.

Employee Perspective

The results presented in **Table 1** (employee perspective) indicate that employees voiced stronger susceptibility concerns regarding the detrimental effects of sitting but as a contributing factor to musculoskeletal pain rather than diabetes. Similar to managers, they attributed diabetes and CVD risk to poor diet choices and lack of exercise "on the road." Although truck drivers recognized the prevalence of diabetes and CVD risk in their profession, perceived severity was lower than the manager perspective. More emphasis was placed on the severity and detrimental effects of stress on the truck driver population. Perceived benefits derived from the survey responses (see **Figure 1**) indicated that stress reduction (3.3 ± 1.3) was the most important motivator and benefit of engagement. Additionally, improved quality of life (3.3 ± 1.3), alertness (3.2 ± 1.4), sleep (3.1 ± 1.4) and pain reduction (2.8 ± 1.5) were considered important motivators. The least important motivator was identified as family support (2.6 ± 1.4). Perceived barriers were similar to those voiced by the managers with an additional concern regarding the availability of safe parking areas which, in some cases, causes drivers to drive for longer than planned. Lack of time to engage in any health solution was consistently identified in both group discussion and survey responses as a significant barrier.

Cues to action identified from survey responses (see **Figure 2**) indicated that participants were most receptive to engaging in physical activity after work (3.1 ± 1.4) but least likely to engage in bodyweight squats during a break to reduce sedentary behavior (1.7 ± 0.8). The survey responses presented in **Figure 3**, indicated that participants were most receptive to the idea of health coaching (2.8 ± 1.4), active rest areas (2.7 ± 1.4) and smartphone prompts after work (2.7 ± 1.5). They were least receptive to employer enforced active breaks (1.9 ± 0.8). Finally, employees reported that if they were given the opportunity, they would prefer to sit (54.6 ± 38.9%), stand (15.4 ± 23.6%) and move (30.0 ± 31.4%) of the time during their working day. However, the perceived ability to do so was low during the work day, and slightly higher outside of work hours.

DISCUSSION

Efforts to promote health are likely to be ineffective if they ignore what a person values, which influences the appraisal of the risk-benefit ratio for different treatments or lifestyle practices (25). Application of the Health Belief Model indicated that there was a disconnect between the perceived value of an intervention designed to reduce sedentary behavior between the researcher, managerial and employee perspective. Based on these findings, pertinent insights that may increase perceived value and future engagement in truck driving health interventions are outlined below.

Leveraging Safety as Well as Health

Our results support existing evidence advocating for health interventions in the trucking population that integrate occupational safety with health promotion (26). Initially, managerial hesitancy toward a digital intervention was apparent due to possible driver distraction. However, this hesitancy was reduced when considering the possibility of targeting sleep and alertness outcomes, for which the perceived value was high. Accumulating evidence suggests that obesity (27) and insulin resistance (28) may play a significant role in the pathogenesis of excessive daytime sleepiness (EDS) which is associated with "drowsy driving" and may result in 1,500 road deaths and 40,000 injuries annually (27, 29). Interestingly, research

TABLE 1 | Managerial and employee perspectives categorized by the Health Belief Model constructs.

Health Belief Model construct	Managerial perspective (I)	Employee perspective (F) (S)
Perceived susceptibility	Voiced concern regarding the prevalence of diabetes and CVD risk in the trucking population	Highly aware of a detrimental relationship between prolonged sitting and musculoskeletal pain
	Awareness that sitting may contribute to health risk but see lack of overall exercise and poor nutrition as the main culprits	Voiced concern regarding unhealthy diet choices due to trucking rest areas and susceptibility to diabetes
	Do not necessarily see strong link between poor glucose control and sitting, i.e., awareness that sitting may contribute to health risk but see lack of overall exercise and poor nutrition as the main contributors to poor health	Acknowledged lack of time to exercise routinely, particularly when on the road and that this may contribute to diabetes, weight gain and overall poorer cardiometabolic health.
	Acknowledgment of truck driver health being an area for concern.	
Perceived severity	Highest priority is the cyclical relationship between poor health, poor sleep and resultant alertness on the road.	Concern regardng the prevalence of obesity and diabetes in truck driver population but attributed this to diet and exercise (not sitting) (F)
	Voiced concern regarding the impact of diabetes in the trucking population	
	Acknowledgment of the detrimental impact of an aging truck driver population and poor health on the ability to recruit new truck drivers into the profession	
Perceived benefits of solutions	Improved driver safety	Reduced stress (S)
	Improved professional reputation and resultant employee recruitment	Improved QOL (S)
	Improved driver health	Improved sleep and alertness (S)
	Improved driver QOL	Reduced MSK pain (F)
Perceived barriers to solutions	Uncertainty regarding the effectiveness of smartphone solutions which may serve as a distraction while driving	Lack of time during break
	Driver regulations and policies i.e., 30 min break, 10 h clock.	Lack of safe parking which may cause them to drive for longer
	Truck driving culture and aging population	Being "on the clock"
	Time	*The 14h clock. Work sched/type does not allow such thoughts. We are paid by the mile. We have X amount of time to get all the miles we can. Miles trump everything when you are paid by the mile.'*
	Isolated nature of driving. Limite contact with employees	
	Disconnect between researcher and real world	
Cues to action	Solution that also targets sleep and alertness outcomes	Coaching (S)
	Rest area redesign	Active rest areas (S)
	Signage	Smartphone prompts after work (S)
	Coaching	Interactive tool to track overall health (S)
		Tool that incorporates parking and rest area infromation (F)
Self efficacy	During a shift = **Low** due to the need to drive while seated, and work long hours. May require policy changes.	During a shift = **Low** due to the need to drive while seated, and work long hours. May require policy changes (F)
	Before or after a shift = **High** due to increeased opportunity outside of truck envronment and time constraints.	Before or after a shift = **Medium** due to increeased opportunity but still conflicts with other daily life stresses and responsibilities (F)
		If given the choice at work, truck drivers reported that they would:
		Sit 55% of the time
		Stand 15% of the time
		Move 30% of the time (S)

Data collection type denoted as Interview (I), Focus group (F) or Survey (S).

has also indicated that intermittent bouts of LPA have been linked to increased alertness (30, 31). Leveraging this evidence and incorporating it into a multi-component intervention may increase the perceived value within the trucking driving community. To increase perceived value from all parties, future interventions should consider additional measures of sleep and alertness (in addition to activity levels and glycemic control).

Social Ecological Determinants of Health

Both employers and employees voiced concern regarding factors outside their control- hours of service laws and parking availability at either rest areas or truck stops which dampened any efforts to engage in health interventions. These results support the notion that determinants of health extend beyond individual lifestyle and health services factors, with social,

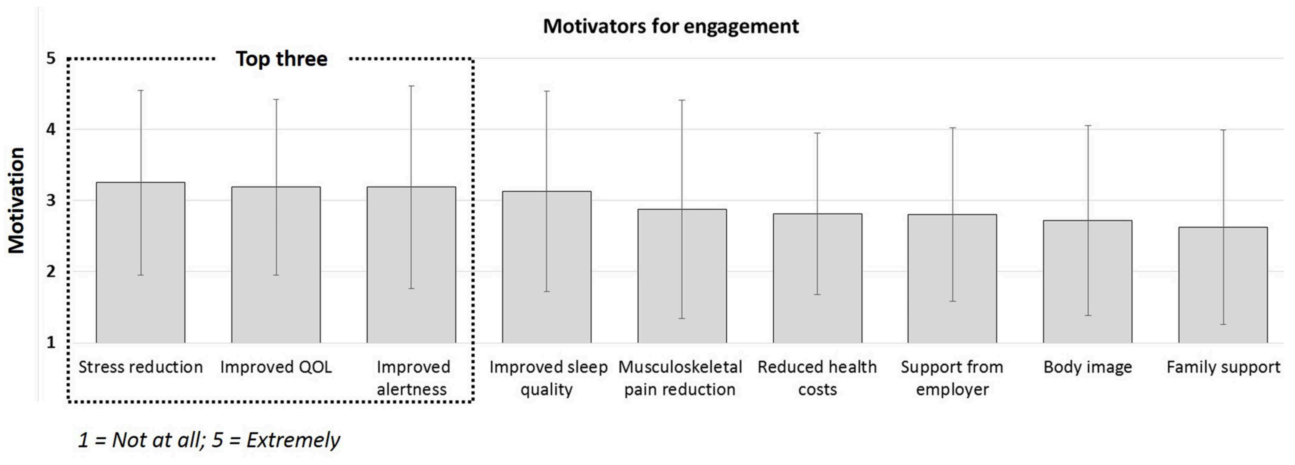

FIGURE 1 | Employee motivators for engaging in preventative behaviors to reduce sedentary behavior (not at all [1] to extremely [5]).

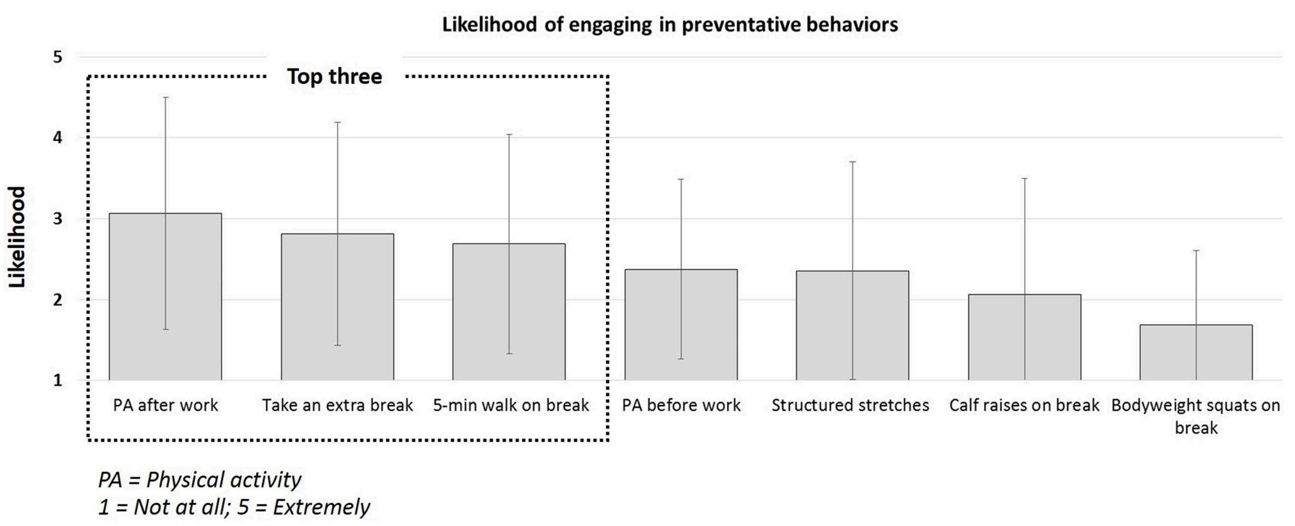

FIGURE 2 | Employee likelihood of engaging in preventative behaviors to reduce sedentary behavior (not at all [1] to extremely likely [5]).

economic, organizational, environmental, and cultural factors all determinants in health (17). Ecological domains, such as governmental, corporate, organizational, community, and built-environment factors, can support or inhibit opportunities and resources available for physical and recreational activities (32, 33). Alternatively, both managers and employees expressed increased perceived value in efforts to promote active rest areas. This is in support of previous research which identified highway rest areas as the highest scoring active living setting for the truck driver population (35.3%) compared to warehouses which were identified as the lowest scoring (11.6%). We recommend that researchers engage multiple stakeholders representing key user personas early in the design process. This may help identify motivators and barriers at the individual, social, cultural and organizational level, and facilitate translation into real world settings.

The Importance of the End-User

Emerging theories suggest that lack of user involvement early in the intervention design process has been identified as one of the major contemporary difficulties encountered during intervention implementation (34). While it is important to acknowledge the high perceived value of safety from the managerial perspective as a motivator to facilitate health intervention for employees, it is important to not lose sight of those who will ultimately participate- i.e., truck drivers. Stress reduction and improved quality of life were perceived as the greater motivators and may therefore be a key component for engagement. We recommend that researchers be creative in the design of an intervention to incorporate higher priority factors as perceived by the end-user, rather than focusing on the researcher and/or stakeholder primary aim alone, e.g., improved glycemic control or alertness.

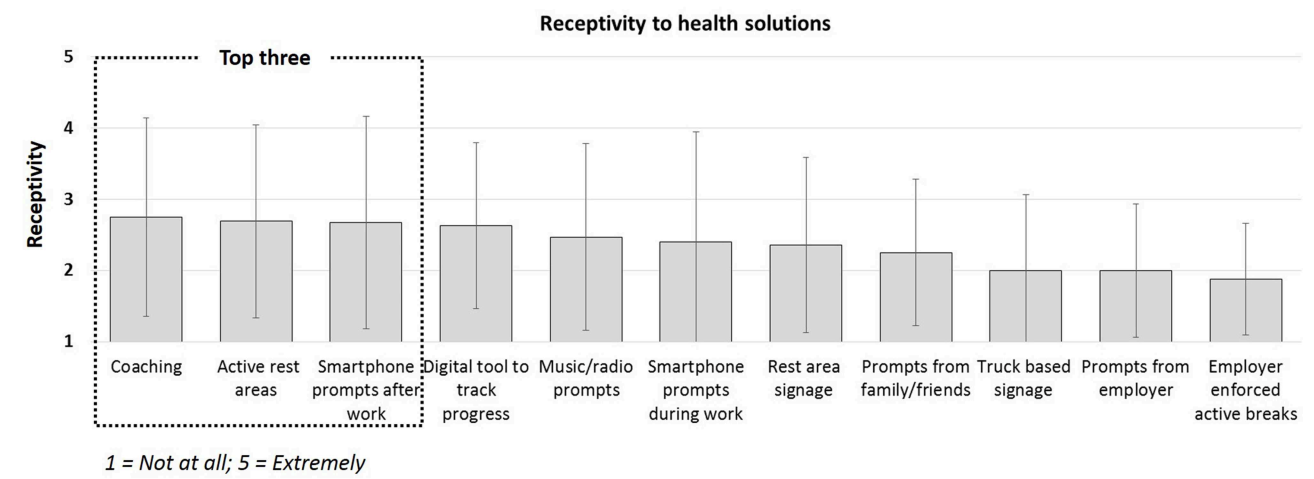

FIGURE 3 | Employee receptivity to sedentary behavior reduction intervention components (not at all [1] to extremely [5]).

Applying Health Communication Theory

In addition to designing for the end-user, researchers may need to incorporate Health Communication theory to better communicate benefits that resonate with the target population (35). The power of effective communication and "framing," or conversely, the impact of miscommunication, is reflected in our results. Conflicting priorities are evident between the likelihood of engagement in behaviors (**Figure 2**) and receptivity to potential health solutions (**Figure 3**). Although "taking an extra break" was identified by employees as the second most likely behavior they would engage in to reduce sedentary behavior, "employer enforced active breaks" was the least preferred health solution. The terminology "enforced" eludes to having less control over the working day and although it would indeed reduce sedentary behavior, the negative perception of less control from the employee perspective may impact employee morale, cause more stress and reduce quality of life. We posit that redefining this option as "support from employer to take an active break," may have elicited a more favorable result. Researchers should be encouraged to consider the unintended consequences of health solutions and health communication, which although may align with researchers and stakeholder goals, may detrimentally impact the end-user perception (36).

Measures and Method of Data Collection

Truck driving is reported as a primarily isolated profession that does not require regular group based contact with work colleagues (17). Therefore, the employer has intermittent contact with each employee. Only ∼32% of the surveys were completed online, the rest were completed on paper. Email communication is not required for the job and thus, the employer does not have an email address for all employees. This reduces the opportunity for interaction with employees and may impact both recruitment and assessment strategies for future trials. Only by gaining trust and through support from the employer were we able to collect a small number of survey responses. The difficulty experienced during recruitment, is reflective of the challenges faced in previous studies reporting low engagement or high attrition (1, 17), and further highlights the need to incorporate our recommendations to; include safety as well as health outcomes, use multi-level strategies, design for outcomes of greater perceived value and communicate the benefits that resonate with the end-user.

LIMITATIONS

We acknowledge that these insights are not generalizable given the small sample size. Similarly, formative research was not audio recorded and there was little variation across the receptivity and motivators for engagement results. However, using rapid assessment processes, we obtained early user feedback quickly and cost-effectively, that may significantly impact intervention design. Too often, researchers do not provide enough insight regarding user research and resultant design decision-making process that may help to inform future research. This is supported by Yeager et al. (37), who recently proposed a framework for "Design Thinking for Psychosocial Interventions" defining different "lenses" to incorporate users i.e., participants, communities, stakeholders etc., early in the intervention design process to avoid easily discoverable flaws that impede real world application (37). Such novel insights are also shared by Community-Based Participatory Research (CBPR)-which aims to unite health professionals, academics, and communities in giving underserved communities a genuine voice in research to increase the likelihood of an intervention's success (38). An important facet of CBPR is the identification of "gate keepers" within the community- without their support and collaboration, an intervention is likely to fail regardless of community demand (38). Our formative research has nurtured relationships and fostered negotiation to provide a more sustainable partnership that can support real world application.

CONCLUSIONS

Truck drivers are exposed to prolonged sitting and rest areas are not perceived as "healthy" environments, and the associations between, obesity and insulin resistance could be fatal. However, the disconnect between what a researcher may perceive as a valuable intervention may not be reflected in the target population. Establishing perceived value is critical to health solution dissemination and true health impact and may require some negotiation in order to gain "buy-in" (not necessarily consensus) from all parties involved. Identifying motivators to participation may impact the intervention measures and communication of the study and should be considered when designing within the community. Such findings can be elicited quickly, cost-effectively and early in the design process using rapid assessment processes to collect and analyze qualitative data. Our findings indicated that while prolonged sitting may be considered a major topic within research, it is yet to resonate with the truck driving population as a "health risk." Although a researcher may endeavor to target a specific behavior, if the value of the perceived intervention is not high enough, it is unlikely that the participant will continue to engage in the preventative behavior. The ability to design sustainable interventions is crucial to public health impact and must be aligned with perceived value of the intervention. There is continued need for user feedback from truck drivers and associated stakeholders to understand the perception of sedentary behavior and potential receptivity to reducing it, to improve the level of engagement and resultant effectiveness of future trials.

ETHICS STATEMENT

This study was approved by the Arizona State University Institutional Review Board and all participants consented using an online or paper based consent form.

AUTHOR CONTRIBUTIONS

SM was responsible for the concept and design of the study. SM and DC were primarily responsible for data collection. SM performed data analysis and interpreted the data. SM wrote the initial draft of the manuscript. SM, MB, and DC reviewed and edited the manuscript, and approved the final version prior to submission. All authors reviewed and approved the final manuscript as submitted.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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