

Using the Behavior Change Wheel to Understand University Students' Prolonged Sitting Time and Identify Potential Intervention Strategies

Oscar Castro^a; Ineke Vergeer^a; Jason Bennie^a; Jonathan Cagas^{a, b}; Stuart J.H. Biddle^a

^aPhysically Active Lifestyles Research Group (USQ-PALs), Institute for Resilient Regions, University of Southern Queensland, Springfield Central 4300, Queensland, Australia.

^bDepartment of Sports Science, University of the Philippines Diliman, Quezon City 1101, Metro Manila, Philippines.

Author	Email address	Orcid ID
1. Oscar Castro (corresponding author)	Oscar.CastroSerrano@usq.edu.au	0000-0001-5332-3557
2. Ineke Vergeer	Ineke.Vergeer@usq.edu.au	0000-0002-6560-9023
3. Jason Bennie	Jason.Bennie@usq.edu.au	0000-0002-8668-8998
4. Jonathan Cagas	Jonathan.Cagas@usq.edu.au	0000-0003-0233-4023
5. Stuart J.H. Biddle	Stuart.Biddle@usq.edu.au	0000-0002-7663-6895

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Abstract

Background: Several national public health guidelines recommend individuals minimize time spent in prolonged, continuous periods of sitting. Developing effective interventions to break up sitting, however, requires in-depth understanding of the behavior as well as identification of the key elements that need to be targeted to achieve change. This qualitative study focused on university students – a highly sedentary group – with the aim of: (i) exploring the factors influencing prolonged sitting time in this population; and (ii) identifying potential avenues for future intervention, based on the Behavior Change Wheel framework.

Methods: Eighteen ambulatory undergraduate students participated in semi-structured one-on-one interviews, using the Capability, Opportunity, Motivation, Behavior (COM-B) model and the complementary Theoretical Domains Framework (TDF) as the theoretical framework. Data were analyzed using a directed content analysis approach, followed by inductive thematic analysis. **Results:** All COM-B components and eight TDF domains were identified as relevant for influencing the target behavior. **Conclusion:** Findings suggest that interventions and policies aimed at reducing prolonged sitting time in university students should: (i) raise awareness about negative health implications; (ii) address productivity concerns; (iii) provide training in behavioral self-regulation; (iv) use external reminders; (v) implement habit formation techniques; and (vi) promote social acceptability for breaking up sitting.

Keywords: college students; sedentary behavior; sedentary time; intervention mapping; implementation research.

Introduction

High levels of sedentary behavior – waking activities that involve sitting or reclining and a low amount of energy expenditure [1] – are associated with an increased risk for adverse health outcomes, such as all-cause mortality, type 2 diabetes, metabolic syndrome, cardiovascular disease, and depression [2-5]. Of note, the health risks of ‘too much’ sedentary behavior have been shown to be somewhat independent of meeting current physical activity guidelines [6]. While moderate-to-vigorous physical activity can counteract the associations between sitting time and all-cause mortality, physical activity levels that are considerably higher than current recommendations seem to be needed to eliminate the negative effects of time spent sitting [7].

University students are a population sub-group at risk of accumulating high levels of sitting time, as activities such as attending lectures and studying likely involve sitting for long periods [8]. Evidence from a recent meta-analysis indicates that university students report spending seven to eight hours sitting per day, with accelerometer-based estimates commonly two to three hours higher [9, 10]. Research thus suggests that university students are highly sedentary [11], and that their daily sitting time is comparable to those of desk-based office workers [12]. Since many health-related behaviors are established during adolescence and young adulthood, the university years are an important period for the development of a lifelong healthy lifestyle [13].

In addition to total sitting time, the manner in which it is accumulated is also relevant. Many national public health guidelines state that individuals should not only minimize sitting time but also introduce regular breaks from long periods of sitting (e.g., Australia [14], Germany [15], United Kingdom [16]). This recommendation is based on epidemiological and experimental evidence suggesting that accumulating sitting time in prolonged, uninterrupted

bouts is more detrimental to health than accumulating sitting time in short bouts [17-22]. Previous studies reporting positive cardiometabolic outcomes have prompted breaks ranging from two to four minutes in length every 20-30 minutes of sitting [23]. However, preliminary evidence indicates that over 40% of the total sedentary bouts spent by university students exceeds 30 minutes in duration [24].

Aside from the physiological benefits, interrupting prolonged sitting may also be relevant for cognitive performance. In previous qualitative studies with office workers, participants reported breaking up their sitting to ‘refresh’ their mind and enhance work productivity [25, 26]. Moreover, in a recent study examining the relationship between accelerometer-based sedentary behavior and academic achievement, it was found that university students who interrupted their sitting time every 20 min during weekdays had higher academic scores [24]. Authors suggest that frequent breaks have the potential to enhance sustained attention and other cognitive operations associated with academic performance [27-29].

In summary, evidence suggests that interrupting prolonged sitting time with short physical activity breaks has the potential to benefit university students’ health, as well as key study-relevant cognitive processes. Breaking up prolonged sitting, however, requires behavior change. When aiming to change behavior, it is important to rely on a comprehensive and systematic approach to intervention design, underpinned by a model of behavior and theoretically predicted mechanisms of action [30]. The Behavior Change Wheel [31] provides a theory-driven intervention development framework, including three main steps: (i) understanding the target behavior, (ii) identifying intervention functions and policy categories, and (iii) identifying intervention content and implementation options (supplementary file 1 - BCW process). While other intervention design frameworks are

available, the BCW is the only one that features a model of behavior, and it is sufficiently broad to cover the full range of factors that potentially affect behavior [32].

The first step within the BCW involves using the Capability, Opportunity, Motivation, Behavior (COM-B) model and the complementary Theoretical Domains Framework (TDF) to identify what needs to change for the behavior to shift in the desired direction ('behavioral diagnosis'). The COM-B model is the BCW's core element and posits that behavior is part of an interacting system involving capability, opportunity, and motivation. Behavior change initiatives need to target one or more of these components in such a way as to put the system into a new configuration (i.e., is greater Capability, more Opportunity, and/or stronger Motivation required in order to achieve change?). The complementary Theoretical Domains Framework (TDF) is an integrative framework of behavior change constructs that can be used to provide a broader and more detailed understanding of the COM-B components [33]. An overview of the 14 TDF domains linking to the COM-B components is available as an online supplementary material (file 2 - TDF with definitions and constructs).

Based on the results from the 'behavioral diagnosis', step 2 consists of selecting appropriate intervention functions (i.e., broad categories of means by which an intervention can change behavior, such as education, training, or persuasion) and supporting policies (i.e., decisions made by authorities that influence behavior, such as fiscal measures, communication / marketing, or legislation). Having identified relevant intervention functions and supporting policies, step 3 involves specifying which Behavior Change Techniques (BCTs) best serve the interventions functions, as well as their mode of delivery. The BCW provides guidance for steps 2 and 3 by highlighting which intervention functions, policy categories, and associated BCTs are expected to bring about change for each of the COM-B and TDF domains, based on a synthesis of 19 existing intervention development frameworks and a consensus exercise by a group of experts [32]. However, these steps cannot be

conducted unless there is a proper understanding of the target behavior (step 1), so that it is possible to identify the key factors that need to be targeted in order to achieve change. That is, understanding the factors related to prolonged sitting is a critical step prior to developing effective behavior change interventions.

Very few studies to date have explored the perceptions of sedentary behavior in university students, with most of the qualitative research among working-aged adults concentrating largely on office workers [25, 26]. Deliens et al [34] conducted focus groups to identify determinants of physical activity and sedentary behavior in undergraduate students. Students reported that their sedentary behaviors were influenced by individual factors (e.g. perceived enjoyment, self-discipline), social networks (e.g., parental control, modelling), and the physical environment (e.g., availability and accessibility of TV/computer). However, the study authors did not report using any theoretical framework and focused on overall sedentary behavior, without exploring the factors influencing breaks in (prolonged) sedentary time. Therefore, the aims of the present qualitative study were twofold: (i) to use the COM-B and TDF approaches to provide a better insight into the factors influencing prolonged occupational sitting among university students; and (ii) to highlight potential avenues for future intervention development based on the BCW framework.

Method

Ethical approval was obtained from the University of Southern Queensland's Human Research Ethics Committee (No. H18REA237). The Consolidated Criteria for Reporting Qualitative Research (CORE-Q) were used to guide reporting (supplementary file 3).

Study Design

A qualitative study was planned using semi-structured one-on-one interviews with university students.

Sampling and Recruitment

Participants were eligible if they were (i) ambulatory, (ii) over 18 years of age, and (iii) undergraduate, full-time, on campus students from the School of Commerce at the University of Southern Queensland (Australia). The USQ School of Commerce, with approximately 4,000 undergraduate students, offers courses in areas such as accounting and commerce, business economics, and finance. This particular school was chosen because coursework mainly involves sitting-related activities, rather than fieldwork or laboratory hours common in some other disciplinary areas. Participants had no previous relationship with any of the study authors and were informed that the interview was part of the first author's PhD project. Regarding sample size, previous recommendations on operationalizing data saturation for theory-based interview studies were followed [35]. Fifteen interviews were set as an initial recruitment target (five per study year), followed by a minimum of three additional interviews until data saturation would be reached. A purposive sampling procedure followed by a snowball sampling technique was used to recruit participants. First, a recruitment e-mail was sent to eligible students describing the study and inviting participation. Second, first-year students who had already taken part in the interviews were contacted to explore whether they could recommend other first-year students for participation (snowballing), with a limit of one student per participant. This was done to fulfill the initial recruitment target, as participants who responded to the email were predominantly second- and third-year students. Two students were recruited through snowballing. There were no dropouts during the recruitment process (i.e., all the students who expressed interest in participating were interviewed).

Interview Procedure

The interview guide was developed following existing guidance [36]. It was aimed at eliciting beliefs about the role of each TDF domain in influencing the target behavior, defined

as breaking up sitting time during private academic activities with short movement breaks every 30 minutes (supplementary file 4 - Interview script). According to the BCW, the target behavior needs to be clearly specified in terms of *who* needs to perform the behavior, *what* the person needs to change, *when*, *where*, *how often*, and *with whom*. Apart from local knowledge or research literature, a number of factors are useful when selecting or prioritizing a specific target behavior among other possible alternatives [31], including the: (i) likely impact if the behavior were changed; (ii) likelihood of changing the behavior; (iii) potential ‘spillover’ effects if the behavior were changed; and (iv) ease of measurement. Detailed information on how these factors were applied to select the target behavior is available as an online supplement (File 5 – Definition and selection of target behavior).

The number of questions in the interview guide ranged from one to three per TDF domain. The guide consisted of open-ended, semi-structured questions, with additional prompts used to probe domains in relation to the target behavior if further clarification was needed. It was piloted with two university students. In addition, a member of the research team with expertise in qualitative research (IV) reviewed the pilot interview transcripts. Based on this pilot work, minor changes were made to address issues such as clarity and repetitiveness. For the official data collection, one-on-one interviews were arranged in a private office (on-campus). Interviews were conducted by the first author, who is a PhD candidate with a background in Sport and Exercise Psychology and has completed several qualitative research courses as part of his bachelor and master’s studies. In addition, he completed a seminar focused on thematic analysis prior to the start of the study. Interested participants contacted the first author via email to set up the interview time. All participants provided written informed consent and completed a sociodemographic questionnaire prior to the interview. Two cinema tickets were offered to the participating students as a compensation.

Data Analysis

All interviews were audio-recorded, transcribed verbatim, and deidentified by the first author.

NVivo 11 software was used to facilitate the analysis. Data were analyzed using a directed content analysis approach [37], followed by inductive thematic analysis [38].

Epistemologically, the study is situated within an essentialist/realism paradigm [39], which assumes that theories refer to real features of the world, and that entities exist independently of being perceived. This epistemology guided some of the decisions during the data analyses. For example, thematic analysis was conducted at the semantic level, which means that themes were identified within the explicit or surface meaning of the students' responses, rather than at the latent or interpretative level, which tends to be used within constructivism paradigms [38].

The directed content analyses entailed a deductive approach, in which two researchers (OC and JC) read the transcripts and coded similar responses into the relevant TDF domains following a mutually agreed coding guideline to ensure the reliability of coding [36]. The coding guideline, a set of explicit statements on how the TDF is to be applied to a specific data set, was developed based on team discussion around the first three interview scripts. In instances where responses were coded in different TDF domains by the two researchers, divergences were discussed to establish consensus (81% agreement prior to discussion).

At the second (inductive) stage, one researcher (OC) used a thematic analysis approach to further analyze the data within each TDF domain. Beliefs statements were generated based on similarities across the participants' responses (supplementary file 6 - Example coding TDF). A belief statement reflects a collection of similar responses from at least two participants that provides detail about the students' perceived role of the domain in influencing the target behavior [40]. For example, 'I think it's easy to take a break', 'I think I

could make that work’, and ‘It’s definitely something that could be done’, were responses grouped under the belief statement ‘Breaking up my sitting time is something that is easy to do’ (TDF domain: Beliefs about capabilities). This step resulted in a list of belief statements within each TDF domain. This was reviewed by JC to ensure accurate representation of content. As a result, similar beliefs were merged together and the wording of four belief statements was changed.

Following the above analyses, the beliefs identified within each TDF domain were evaluated with respect to their likely relevance to changing the target behavior. This is known as ‘behavioral diagnosis’ within the BCW terminology, a relevant step to determine what needs to change for the target behavior to occur. In order to judge domain relevance, three criteria were considered concurrently through a consensus discussion within the research team [36]: (i) high frequency of specific beliefs statements across participants, (ii) presence of conflicting beliefs, and (iii) evidence of strong beliefs that might impact on the target behavior. Finally, the identified TDF domains and associated belief statements were linked to intervention functions, policy categories, and BCTs likely to bring about behavior change [31]. Examples of potential intervention strategies were also provided.

Member Checking

In order to enhance the trustworthiness of results, ‘member checking’ techniques were applied remotely after the interview [41]. First, participants received a copy of the interview transcript by email and were invited to add information or amendments if they so wished. Minimal revisions were made by two students. Second, the list of belief statements was sent to all participants asking for feedback regarding resonance with their own experiences. Five responses were received, with a general agreement about the validity of the main study

findings. Based on the students' feedback, refinements were made to the wording of two belief statements.

Results

A total of 18 undergraduate students, aged 18–27 years (23 ± 2.53 years), were interviewed, of which 11 were women (Table 1). Interviews ranged from 27 to 41 minutes in duration, with a mean of 35.3 minutes per interview ($SD = 4.65$). Data saturation was reached after 15 interviews, with no new themes identified in the last three interviews (stopping criterion). Overall, the students reported a range of belief statements regarding the target behavior. The identified beliefs for each COM-B and TDF component are described below. In addition, supplementary file 7 includes a full list of belief statements, as well as their frequency across interviews and example quotes from participants.

[INSERT TABLE 1 HERE]

Psychological Capability

Interviews revealed most students lacked knowledge about the adverse health risks of prolonged sitting time. There was consensus among the students that providing more information in this regard would be beneficial for motivating behavior change. Responses also highlighted that the students' decision process involved in taking breaks tended to be automatic, provoked by body sensations such as tiredness, thirst, or stiffness, rather than a conscious decision to perform the behavior. For many students it was difficult to remember taking breaks, as university activities are absorbing and mentally demanding.

Moreover, while most students reported using different strategies to self-monitor their study and break patterns (mainly looking at a computer or wrist/smartphone clock), they rarely employed external reminders such as timers or alarms. Some students appeared to be

reluctant to use these ‘invasive’ reminders (e.g., an alarm) and preferred to use their own strategies, such as using playlists with a set duration or periodically refill their water bottles.

Reflective Motivation

Participants made conflicting comments as to whether breaking up sitting time is part of the student role / identity. Some perceived that tasks such as studying or writing assignments are the only ones central to the student role; others suggested a more holistic view where students should also take care of themselves, including taking regular breaks, engaging in regular physical activity, and having proper nutrition.

In relation to specific beliefs about capabilities, there was a general agreement among the students that interrupting sitting time during private academic activities is feasible. Students identified both positive and negative consequences of breaking up their sitting time. Over half of the participants indicated that frequent movement breaks would be beneficial for their physical health, as well as their concentration and fatigue levels. Nevertheless, there were also common concerns about the negative impact that breaks might have on performance, in terms of increased distractions.

Related to the common complaint that breaks might impair performance, many answers reflected a goal conflict between carrying out university tasks and taking frequent movement breaks. Additionally, several students’ responses reflected a lack of motivation to introduce additional movement breaks to their study time.

Automatic Motivation

Some participants expressed the view that taking movement breaks does not evoke any emotional response, whereas others felt the opposite, including both positive and negative responses. Taking breaks is helpful to reduce stress and anxiety according to some

students. However, students also mentioned that breaks might trigger a stress response, especially when the workload is high. Several students also highlighted that in order to perform the behavior it needs to become an ingrained (automatic) habit. In addition, snacking or having a hot drink were viewed as potential incentives for taking breaks.

Physical Opportunity

Students identified several environmental factors influencing the frequency of breaks in sitting time. The closeness of university-related deadlines was identified as a possible source of variation, with many participants stating that they are less likely to take breaks as deadlines approach. The nature of the task was also identified as an important factor. Participants reported that it is easier to take breaks in certain tasks, such as watching a recorded lecture. A further factor influencing the frequency of breaks was the physical environment. Some students perceived that it is easier to break up sitting time at home, as opposed to the library or other shared settings.

Social Opportunity

Participants identified both positive and negative social influences for taking movement breaks. Students described that many breaks are initiated by social interactions with peers or relatives, and that seeing other students taking breaks can trigger them to do so. However, some students highlighted that the presence of other individuals can prevent them from taking breaks. Reasons included fears of getting distracted or experiencing disapproval from other students.

Behavioral diagnosis

Belief statements coded from the students' responses were subject to a behavioral diagnosis to identify what needs to change in the person and/or the environment for the behavior to shift

in the desired direction. For example, the more frequent belief statements within the TDF domain *knowledge* were 'having more information about the positive consequences of breaking up sitting would make me more likely to do so' and 'I don't know too much about why it's important to break up my sitting time' (supplementary file 7 - Belief statements). Therefore, it was surmised that one thing that needs to change for the students to break up their sitting time is knowing that accumulating sedentary time in prolonged, uninterrupted bouts is detrimental to health. A complete behavioral diagnosis of the relevant COM-B and TDF components is presented in Table 2, including potential BCW-indicated intervention strategies and policies to address the factors influencing prolonged sitting.

[INSERT TABLE 2 HERE]

Discussion

Current public health guidelines advise ambulatory individuals to minimize time spent in prolonged, continuous periods of sitting. Developing effective interventions to break up sitting, however, requires an in-depth understanding of the behavior as well as identification of the key elements that need to be targeted in order to achieve change [31]. To the best of our knowledge, the present study is the first to investigate the factors influencing prolonged occupational sitting in university students, a highly sedentary population sub-group. All COM-B components were identified by the students as relevant for influencing the frequency of breaks in sitting time. These components aligned with eight TDF domains: Knowledge; Memory, attention and decision processes; Behavioral regulation; Social / professional role and identity; Beliefs about consequences; Intentions; Reinforcement; and Social influences. By using the procedures within the BCW, we were also able to highlight relevant strategies and behavior change techniques for future intervention development.

In relation to knowledge, while students recognized general benefits of breaking up sitting, many of the adverse health risks associated with prolonged sitting were unknown. Our sample of students agreed that having more information on why it is important to break up prolonged sitting would be helpful to motivate behavior change. This is consistent with previous qualitative work [34] and highlights that ‘sedentary behavior’ is still a relatively new concept among university students, often confused with lack of physical activity (e.g., walking, cycling). Results imply that more education is needed regarding prolonged sitting and its association with overall health. Public health messaging by universities or other organizations working with students might provide a wide-reaching and cost-effective strategy to raise awareness and change sitting patterns, especially if messages emphasize attainable, specific, and healthy alternatives to sitting such as standing or being active [42]. Education sessions have been found to be an effective behavior change mechanism to reduce sitting and increase movement throughout the day among office workers [43]. Studies are needed to examine whether such strategies are effective in the university setting.

Another common topic of discussion during the interviews was the potential effects of breaking up sitting on academic performance. Students held mixed views, with some thinking that having regular breaks can lead to improved thinking and sustained focus, while others indicated that it would harm productivity and disrupt their concentration. The concern that breaking up and reducing occupational sitting might hinder work productivity is consistent with previous studies with office workers [25, 26], and is a key belief to be targeted in order to facilitate behavior change. Interventions could try to emphasize breaking up sitting as a way of having a ‘mental break’ from academic tasks or, alternatively, provide suggestions on how to break up sitting whilst still working efficiently (e.g., highlight tasks that can be undertaken standing up or walking).

Our findings highlight that social influences are relevant when it comes to breaking up sitting. According to the students, the presence of other people might inhibit breaks, due to concerns of being distracted during the break or being perceived by others as engaging in an ‘awkward’ behavior. Concerns about the social acceptability of breaking up sitting are also common among office workers [44, 45]. Behavior change efforts need to take into account that there is an implicit norm to sit in many contexts, preventing people from changing their sitting patterns in shared settings (e.g., library, lecture theatres). Finding strategies to promote the social acceptability of breaking up sitting should be an important component in the development of future interventions, especially when targeting adolescents and young adults, as research consistently shows that their health choices are greatly influenced by peers [46]. An interesting example of such strategy has been reported by the Belgian university KU Leuven, where lecturers are encouraged to appoint a ‘stand-secretary’ at the beginning of their lectures. This is, a student entitled to stand up at random times, providing a sign for other students to stand up and stretch. The initiative uses modelling by other students to raise awareness of the importance of regularly interrupting long bouts of sitting [47].

Several students referred to automatic processes such as habits and routines when discussing the target behavior. The available evidence suggests that sitting is indeed habit-based [10]. Habit is a learned behavior triggered by environmental cues with limited cognitive influence [48]. This is somewhat reflected in students’ responses that indicated that breaking up sitting time was mostly an automatic decision based on body sensations such as feeling sore or tired. Previous studies have used habit formation strategies aimed at changing sitting patterns, for example, asking participants to pair standing breaks with daily habits such as talking on the phone or drinking coffee [49]. Increasing awareness and using environmental cues to break up sitting time is hypothesized to disrupt the habit of sitting,

helping people to stand up and move more frequently [50]. Over time, the environmental cues might not be needed as the decision to break up sitting becomes automatic.

Finally, in order to change their sitting patterns, it is important that students know how to manage and regulate their own behavior. Based on our behavioral diagnosis, we suggest that goal-setting, action planning, and problem solving are potential self-regulatory skills that can assist the students in breaking up sitting. Indeed, in a review exploring BCTs that have been effective in reducing sitting time among adults, self-regulatory skills training was identified as a particularly promising strategy, along with restructuring the physical environment [51]. Changes in the physical environment usually include provision of standing desks and use of prompts or other environmental cues. In our study, students reported that the use of external reminders would be useful to notice and remember to break up sitting. However, certain strategies (e.g., setting an alarm) do not seem acceptable for some students and intervention developers might need to take a personalized, case-by-case approach.

Recommendations for Future Research and Intervention Development

Sitting is a highly prevalent behavior, occurring in different contexts and with varied purposes. This presents a challenge for researchers and intervention developers; there is a balance between being highly behaviorally specific (to precisely identify what factors need to be changed) and being general enough to be relevant to a range of settings (maximizing the likely impact if the behavior were to be changed). Based on the BCW framework, it is argued that a specific description of the behavior helps to determine the sources of implementation problems, pinpointing what needs to be changed, thus increasing the chances for the intervention to be effective [32]. For example, an intervention to promote breaks from occupational sitting time might need to target different factors depending on the context (i.e., breaks during private academic activities vs breaks during lectures). Unlike private study

time, breaking up sitting during lectures might require policy and curricula changes, along with modifications in how lecture theatres are built. That is, despite both behaviors qualifying as occupational sitting, they would require a specific behavioral diagnosis and, potentially, different intervention approaches. Researchers should consider this issue and make their own decisions on the appropriate level of behavioral specificity for sedentary behavior.

Intervention developers should also consider the specific behavioral target(s). Sedentary behavior interventions typically focus on breaking up sitting time, reducing overall sitting, or changing both behaviors simultaneously. Some authors argue that, for university students, breaking up existing occupational sitting time into shorter bouts might be more feasible than displacing large volumes of daily sitting time to standing or moderate-to-vigorous physical activity [52]. We consider that the two behaviors are closely related, and that some of the strategies identified in the present study could also be applied in sitting time reduction interventions (e.g., provision of information about health consequences, self-regulatory skills training, use of environmental cues). Previous studies have explored the factors influencing overall sitting time in university students [34]. These could be used to complement our findings and inform interventions aiming at both reducing and breaking up sitting.

Future studies might also explore the influences of non-occupational sitting and assess whether (i) they differ from the factors associated with variation in occupational sitting, and (ii) change is more or less feasible (i.e., students perceive it might be easier to introduce change in one or the other). Moreover, many participants believed that breaking up sitting might have negative implications for working effectively. While some evidence exists suggesting the opposite [24], this is still an understudied area. Further research including measures of productivity is required to strengthen the case for reducing prolonged sitting in the university setting.

Throughout our study, we provided a list of BCTs likely to bring about change for the target behavior, based on a behavioral diagnosis framed within the COM-B and TDF components. However, additional decisions need to be made regarding different intervention dimensions such as mode of delivery (face-to-face or distance?), duration (over what period?), and intensity (what is the number and frequency of contacts during the intervention?). In order to determine the most appropriate mode of implementation, researchers may need to take different factors into account, including the particular characteristics of the target behavior and population group, time and financial resources, as well as evidence gathered from local sources and the research literature.

Strengths and Limitations

A strength of this study is that we used a comprehensive and systematic approach to identify theory-based factors influencing prolonged occupational sitting time in ambulatory university students. Drawing on the COM-B model and associated TDF domains provides a useful framework for understanding behavior and determining the content of future interventions. Moreover, this study adds evidence to the limited literature investigating sedentary behavior in university students. So far, research on sedentary behavior among working adults has largely focused on office workers. Our study has also some limitations that need to be considered. Results are based on a predominantly white sample of undergraduate students. Therefore, findings may not be applicable to all university students. Additionally, broad socio-cultural factors that may influence study habits (e.g., socioeconomic status) were not explored in our interviews and need to be incorporated in future research.

Conclusion

A wide range of beliefs aligning with the COM-B and TDF components were identified by the students as likely to influence their time spent in prolonged occupational sitting. By using

the BCW, our study provided a theory-driven foundation to generate possible behavior change strategies directly from these beliefs. Findings suggest that the following should be key components in future interventions aimed at reducing university students' prolonged occupational sitting: (i) raising awareness about the negative consequences of prolonged sitting, (ii) addressing productivity concerns, (iii) providing training in behavioral self-regulation, (iv) making use of external reminders, (v) implementing habit formation techniques, and (vi) promoting social acceptability for the behavior. Future studies should examine the effectiveness and practicability of these strategies, as well as their potential relevance to other sedentary behaviors and contexts.

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Compliance with Ethical Standards

Conflict of Interest

The authors declare that they have no conflict of interest.

Informed Consent

Informed consent was obtained from all individual participants included in the study.

Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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Table 1. Characteristics of one-on-one interview participants (n = 18).

Variables	% (n), Mean ± SD
Gender (% of females)	61% (11)
Age	23 ± 2.53
Year of study	
1 st year	28% (5)
2 nd year	39% (7)
3 rd year	33% (6)
Major of study	
Business economics	22% (4)
Finance	28% (5)
Accounting	17% (3)
Mixed courses (e.g., finance and accounting)	33% (6)
Race / Ethnicity	
White	89% (16)
Pacific Islander	11% (2)
Employment status	
Student	83% (15)
Student and part-time job	17% (3)
Residency	
On-campus	11% (2)
Off-campus	89% (16)

Table 2. Behavioral diagnosis for target behavior ‘breaking up prolonged sitting time during private academic activities’, along with intervention functions, policy categories, behavior change techniques, and potential intervention strategies.

Behavioral diagnosis using TDF domains linking to COM-B components – What needs to change?	Intervention functions ^a	Policy categories ^b	Behavior Change techniques (BCT v1) ^c	Potential intervention strategies
Psychological capability				
Knowledge - Know that accumulating sedentary time in prolonged, uninterrupted bouts is detrimental to health - Know when and for how long break up sitting, including which activities constitute an effective break from sitting	Education, training	Communication/marketing, guidelines, service provision	Information about health consequences, information about social and environmental consequences, instruction on how to perform a behavior	- Raising awareness about the risks of prolonged sedentary behavior through educational seminars, leaflets, wall posters, or copies of public health guidelines - Provide instruction booklets or summaries of published research on break frequency and duration (dose-response), including strategies to break up sitting
Memory, attention and decision processes - Notice and remember to break up sitting	Enablement, Environmental restructuring	Environmental /social planning, guidelines,	Self-monitoring of behavior, adding objects to the environment, prompts/cues	- Provide a device that monitors sitting time and remind participants to move after 30 minutes of sustained inactivity (e.g., Darma cushion, Jawbone UP, Fitbit)

<p>- Identify the moments or situations where it is more difficult to break up sitting time</p>	<p>service provision</p>	<p>- Instruct the participants to set an alarm for every 30 minutes or other similar strategy (e.g., use playlists with a set duration)</p> <p>- Use prompts at desk as visual cue to break up sitting (e.g. stickers, postcards)</p> <p>- Fill in diaries detailing the sitting patterns for different periods of the day (ecological momentary assessment) and prompt reflection on when is more difficult to break up sitting and why</p>	
<p>Behavioral regulation</p> <p>- Set specific goals in relation to breaking up sitting time</p> <p>- Establish a method to monitor the frequency and duration of breaks</p> <p>- Analyze the barriers to break up sitting and develop strategies to overcome them, this including specific plans for moments or situations where it is more difficult</p>	<p>Education, training, enablement</p>	<p>Communication/marketing, guidelines, service provision</p> <p>Self-monitoring of behavior, feedback on behavior, goal setting (behavior), review behavior goal(s), graded tasks, problem solving, action planning</p>	<p>- Set SMART and increasingly difficult goals to break up sitting</p> <p>- Provide the participant with individually tailored feedback on sedentary time in order to guide goal-setting</p> <p>- Encourage self-monitoring and regular review of goals using a tracking device or a workbook with daily checklists (e.g., “Today, did you achieve your goal of breaking up sitting every 30 minutes while</p>

to break up sitting time (e.g., when deadlines approach)

watching pre-recorded lectures?

Yes/No. If not, what was stopping you?")

- Use action planning to specify when, where, and how participants will break up sitting (implementation intentions)

- Provide guidelines with generic tips to break up sitting time and invite participants to identify strategies specific to their circumstances (e.g., have walking meetings with your classmates while discussing your next group assignment, move around the house while you check your emails on your mobile phone)

- Provide free and accessible behavioral lifestyle counselling services

- Prompt participants to identify potential barriers to break up sitting and discuss ways in which they could overcome them according to the IDEA problem-solving (IDEA:

				Identifying the problem, Develop a list of solutions, Evaluate the solutions, and Analyze how the plan worked)
Reflective motivation				
<p>Social / professional role and identity</p> <p>- Adopt the view that taking breaks might help students to perform their role more efficiently</p> <p>Beliefs about consequences</p> <p>- Challenge the perception that breaking up sitting would disturb the student’s work and concentration</p> <p>- Reinforce the physical and mental health benefits from breaking up sitting</p> <p>Intentions</p>	<p>Education, persuasion</p>	<p>Communication/marketing, guidelines, service provision</p>	<p>Information about health consequences, information about social and environmental consequences, credible source, framing/reframing, instruction on how to perform the behavior, social comparison</p>	<p>- Present data supporting the idea that frequent breaks have a positive impact on health, as well as on cognitive processes related to academic performance (e.g., attention levels, mental fatigue)</p> <p>- Suggest that the participant might think of taking short breaks as a way to ‘refresh’ his attention and improve performance (rather than procrastination)</p> <p>- Provide guidance on how to work efficiently while breaking up sitting. This might include advice on conducting walking meetings, highlight tasks that can be undertaken standing up, or recommend strategies to assist the students in getting back to their work quickly after the break (e.g.,</p>

<p>- Develop intentions to break up sitting during private academic activities</p>				<p>use post-its to specify what it is to be done)</p>
				<p>- Raise awareness about the fact that university students typically show higher levels of sedentary behavior compared to the general adult population and thus should pay special attention to their sitting patterns</p>
<p>Automatic motivation</p>				
<p>Reinforcement</p> <p>- Establish routines and habits to break up sitting time</p>	<p>Environmental restructuring, training, incentivisation</p>	<p>Environmental /social planning, guidelines, service provision</p>	<p>Habit formation, behavioral practice / rehearsal, feedback on behavior, self-monitoring of behavior, prompts/cues, self-reward, social reward</p>	<p>- Prompt rehearsal and repetition of the target behavior in the same context repeatedly so that the context elicits the behavior (e.g., ask the participant to consistently break up sitting while studying in his room)</p> <p>- Use environmental signposting in specific contexts to trigger breaks (visuals cues)</p> <p>- Prompt self-reward and deliver positive reinforcement / praise if there has been progress in breaking up sitting</p>

Social opportunity				
Social influences	Environmental restructuring, restriction	Environmental /social planning, guidelines, regulation	Restructuring the physical environment, social support (unspecified), information about others' approval, identification of self as role model	<ul style="list-style-type: none"> - Advise the students to identify appropriate places to break up sitting so the participant reduces the chance to engage in competing behaviors (e.g., break up sitting by going to the bathroom, instead of going to the university canteen where there is a higher risk of being distracted by other students) - Suggest that the participant's own behavior may be an example for other students to break up their sitting time - Inform the participant that other people approves and encourages taking breaks (e.g., posters or booklets with motivational quotes from other students)
- Identify places where students can break up their sitting time without being distracted by others				
- Promote social acceptability for breaking up sitting				

^a The Behavior Change Wheel describes nine potential intervention functions. This is, broad categories of means by which an intervention can change behavior, including education, training, persuasion, incentivization, coercion, restriction, modelling, environmental restructuring, and enablement [32].

^b The Behavior Change Wheel describes seven policy categories that are likely to be effective in supporting each intervention function. The policy categories represent types of decisions made by authorities that help to support and enact behavior change, including communication/marketing, guidelines, fiscal measures, regulation, legislation, environmental/social planning, and service provision [32].

^c A Behavior Change Technique (BCT) is an ‘active ingredient’ of change and is defined as an "observable, replicable, and irreducible component of an intervention designed to alter or redirect causal processes that regulate behavior" [32]. The Behavior Change Technique Taxonomy version 1 (BCTTv1) includes 93 BCTs grouped within 16 categories and can provide a greater level of intervention detail for synthesis, comparison, and replication of studies.

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