The search for the ejecting chair: a mixed-methods analysis of tool use in a sedentary behavior intervention

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Cite this as: *TBM* 2020;10:186–194
doi:10.1093/tbm/iby106
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Abstract

Research is needed on interventions targeting sedentary behavior with appropriate behavior-change tools. The current study used convergent sequential mixed methods (QUAN + qual) to explore tool use during a sedentary behavior intervention. Data came from a two-arm randomized sedentary behavior pilot intervention. Participants used a number of intervention tools (e.g., prompts and standing desks). Separate mixed-effects regression models explored associations between change in number of tools and frequency of tool use with two intervention targets: change in sitting time and number of *sit-to-stand transitions* overtime. Qualitative data explored participants' attitudes towards intervention tools. There was a significant relationship between change in total tool use and sitting time after adjusting for number of tools ($\beta = -12.86, p = .02$), demonstrating that a one-unit increase in tool use was associated with an almost 13 min reduction in sitting time. In contrast, there was a significant positive association between change in number of tools and sitting time after adjusting for frequency of tool use ($\beta = 63.70, p = .001$), indicating that increasing the number of tools without increasing frequency of tool use was associated with more sitting time. Twenty-four semistructured interviews were coded and a thematic analysis revealed four themes related to tool use: (a) prompts to disrupt behavior; (b) tools matching the goal; (c) tools for sit-to-stand were ineffective; and (d) tool use evolved over time. Participants who honed in on effective tools were more successful in reducing sitting time. Tools for participants to increase *sit-to-stand transitions* were largely ineffective.

This study is registered at clinicaltrials.gov. Identifier: NCT02544867

Key words

Older adults, Sedentary behavior, Technology, Mixed methods

INTRODUCTION

Sitting rates have increased dramatically since the 1960s [1]. Prevalence studies estimate that adults spend over 6 hr per day sitting [2], whereas older adults sit more than 9 hr per day [3]. The fact that individuals are sitting more is problematic because recent epidemiological studies have shown that there are deleterious effects of prolonged sitting time including increased risk of weight gain, metabolic syndrome, diabetes, and heart disease [4]. Even more concerning is that these relationships persist even after adjusting for physical activity.

Implications

Practice: It is unclear what method of breaking up sitting is most beneficial; however, healthcare providers should provide information about this important health topic to older adults but be aware of the challenges in changing this very habitual behavior.

Policy: More specific behavior targeting to improve health is necessary to improve health and clear long-term behavior-change techniques for this behavior outside of work or school settings are not yet available.

Research: With research showing negative effects of sedentary behavior on health, developing effective intervention strategies should be a public health priority.

Although research clearly shows a link between total sitting and health, it is still unclear what type of sedentary behavior is most detrimental. For example, recent research has focused on disentangling how the accumulation of sitting time affects health [5]. Specifically, is it overall sitting time, time spent in prolonged bouts of sitting, or some combination of these behaviors that has the most direct impact on health? Most of the work focused on elucidating these distinctions has been conducted in the laboratory under controlled conditions. A review in 2015 evaluated the results from 14 acute laboratory studies that compared prolonged sitting conditions with a variety of sitting interruption conditions [6] and the relationship with biomarkers. The review concluded that interrupting sitting time had positive impacts on biomarkers for metabolic risk, especially in individuals who were physically inactive. Additionally, a number of observational studies have also identified this link between breaking up sitting time and health. In a large Canadian study, an additional 10 breaks from prolonged sitting was associated with more favorable waist circumference, blood pressure,

triglycerides, cholesterol, insulin, and glucose [7]. In another cross-sectional study, more breaks from sitting were associated with higher fitness scores, even after adjusting for physical activity and total sitting time [8]. Based on these results, it is clear that there are biological benefits to breaking up sitting with standing. Specifically, the physiological benefits from postural changes caused by the action of standing up may have distinct benefits to health that are separate from the physiological benefits associated with physical activity [9]. Given the evidence linking sedentary behavior and health from both laboratory and cohort studies, distinct research is necessary to further explore how to change this behavior in the population.

With the evidence linking negative health outcomes and excessive sedentary behavior [10, 11], there has been a surge of interventions to reduce the behavior. However, changing sedentary behavior can be especially challenging given the sheer exposure to the behavior individuals are faced with throughout the course of the day [12]. Previously, researchers hypothesized that increasing physical activity through interventions would reduce sedentary behavior as a secondary outcome [13]. A review of interventions by Prince et al. discovered that an increase in physical activity does not have a direct impact on sedentary behavior [13]. In contrast, interventions focused on changing sedentary behavior by increasing standing have minimal impact on physical activity, but do show promise for reducing sitting time [14].

Currently, most sedentary behavior interventions have focused on schools and worksites [15] where standing desks are primarily employed. Only a few short-term pilot studies have specifically targeted older adults, with the most successful interventions focusing strictly on changing sedentary behavior and including behavioral feedback from ActivPALs or other monitoring devices in conjunction with individual or group coaching [16–18]. Because most older adults do not work, alternative tools to standing desks require further investigation. Given that older adults struggle to meet physical activity guidelines and accumulate the most sedentary time [19], theory-based interventions that target older adults who are both working and nonworking are essential.

From physical activity studies, we have learned that self-monitoring and cues/prompts are key constructs [20] and these lessons are being translated into the new area of sedentary behavior reduction. Pedometers are one of the most successful tools in physical activity interventions with real-time step counts [21]; there is not yet a similar device for measuring sitting that is wearable and appropriate for everyday wear. Despite the surge in wearable activity devices for physical activity (e.g., Jawbone and Fitbit), these devices do not target sitting time specifically and do not register standing as a way to break

up sitting time; they only provide feedback when steps are accumulated [22]. Additionally, intervention devices currently available do not accurately measure time spent sitting, standing, or the number of *sit-to-stand transitions* which are key targets in sedentary behavior interventions [22, 23]. Although ActivPAL devices worn on the thigh are emerging as the gold standard to assess these key behaviors, and some studies have provided short-term feedback from the ActivPAL during the intervention, the ActivPAL does not yet provide real-time feedback on transitions and time in target behaviors.

Specific interventions with appropriate tools to help participants reduce sedentary behavior over longer periods are needed. Qualitative data could help us better understand participants' attitudes to existing tools employed to reduce sedentary behavior [24]. Understanding the limitations associated with current tools could drive future development of tools that can specifically target sedentary behavior change. To improve our understanding of behavior-change tools employed in sedentary behavior interventions, the current study used a convergent sequential mixed-methods approach (QUAN + qual) to explore how tool use during a pilot intervention affected the targeted sedentary behaviors.

METHODS

Study design and procedures

The Take a Stand study was a two-arm randomized pilot trial funded by the Department of Family Medicine and Public Health at the University of California, San Diego. The study was designed to test the feasibility and acceptability of a short-term sedentary behavior intervention [16]. Thirty participants, with an equal number of workers and nonworkers, were recruited to participate in a 2 week sedentary behavior intervention following a screening week. Participants were enrolled who agreed to participate and met the following inclusion criteria: (a) aged 50–70 years; (b) spent at least an average of 8 hr per day sitting over 5 days; (c) able to attend four measurement visits at the UCSD campus in four consecutive weeks; (d) willing to wear a thigh-mounted inclinometer 24 hr per day for the entire 21 day study duration; (e) able to read and write in English; (f) provided written informed consent; and (g) without a serious health condition that would limit their ability to stand. Participants were assessed by ActivPAL for a 1 week run-in screening period and continued to wear the ActivPAL for the remaining 2 week intervention.

Intervention conditions

Participants ($N = 30$) were randomly assigned to either a “*sit less*” condition where participants were asked to reduce the total amount of sitting time per day by 2 hours or a “*sit-to-stand transition*”

condition in which participants were asked to add 30 *sit-to-stand transitions* each day. Participants in the “*sit-to-stand transition*” condition were instructed that the transitions could be brief as a means of avoiding interrupting normal activities. *Sit-to-stand transitions* were targeted separately because previous studies have not succeeded in increasing this behavior, probably because they had focused on increasing standing, which reduces the number of sit-stand opportunities. We hypothesized that focusing solely on frequent transitions would be more effective and potentially have different health impacts [9] when compared with prolonged standing. We chose to focus on a 2 hr reduction in sitting because we wanted to test whether we could replicate similar findings from previous trials [25] in a population of older adults who were both working and nonworking.

Intervention overview

The intervention components were developed to emphasize Abraham & Michie’s 26-item behavior change taxonomy [26] and included constructs such as goal setting, feedback, prompts and cues, and self-monitoring which have been shown to be important in previous interventions. Unlike the intervention paper that reported on the main effect of a significant decrease of 130 min of sitting time in the “*sit less*” condition and 13 additional transitions in the “*sit-to-stand transition*” condition compared with baseline [16], the current study focused on intervention weeks only and the tools employed because tools were only distributed and used during that time (Fig. 1). The objective of the current analysis was to examine how participants achieved these changes, specifically if and what aspects of tool use facilitated behavior change.

Participants came in for study activities each week during the pilot (Fig. 1). During each intervention weekly session, participants in both conditions met with a health educator to review their sedentary behavior from the previous week focusing on either total sitting time or *sit-to-stand transitions*, depending on the condition. The data from the ActivPALs were processed to provide participants with a daily breakdown of their sedentary behavior over the course of the previous week (Figs. 2 and 3). This allowed participants to develop a plan to accomplish the goal based

on their routines. With the health educator, participants developed an appropriate action plan to incorporate into the following week to work towards the goal. The participants discussed strategies to either reduce their sitting time or increase *sit-to-stand transitions* based on their routine and regular activities.

Participants in both conditions were provided with a variety of tools to support the distinct goals that targeted the aforementioned behavior-change constructs including self-monitoring and prompts/cues [26]. The tools were a combination of physical tools, virtual reminders, or visual cues and prompts. Individuals in the “*sit less*” condition were provided with 13 tools that included standing desks, program timers to disrupt sedentary behavior (e.g., smartphone apps and computer program apps), physical timers that could be placed in a variety of locations (e.g., work desk, on top of TV and kitchen counter), a vibrating watch that could be set for reminders, a brightly colored, branded study bracelet with the study tagline that served as a visual cue, a bookmark and card with the study logo and description, notepad and dry erase board to write notes, and reminders via various communication mediums such as text messages, emails, or phone calls from study personnel to work on the behavior change. Participants in the “*sit-to-stand transition*” condition were provided with the same tool choices as the “*sit less*” condition and were also provided with an electronic counter to track the number of transitions taken throughout the day. Because the transitions were designed to be brief, they were not provided with standing desks.

MEASURES

Quantitative data: ActivPAL

The thigh-mounted inclinometer called the ActivPAL (PAL Technologies Limited, Glasgow, UK) was used as the primary objective measure of sedentary behavior for the entire pilot intervention. The ActivPAL detects daily sitting time, standing time, stepping time, and number of *sit-to-stand transitions* [27]. To omit sleep time from these measures, participants completed a log to document sleep time and daily waking hours. Because sleep can greatly affect the number of available waking hours for sedentary behavior [27], it was important to analyze sedentary behavior changes while accounting

Fig. 1 | Timeline of study activities in the Take a Stand intervention.

Fig. 2 | Sample feedback graph for the “sit less” condition. Red indicates extended bouts of sitting.

Fig. 3 | Sample feedback graph for the “sit-to-stand transition” condition. Green indicates sit-to-stand transitions.

for sleep time. Participants were provided with a waterproofed device and during the first visit they were instructed how to apply the device with adhesive tape. Although participants were provided with replacement sleeves for the device, they were encouraged not to remove the device between study visits to maintain waterproofing during bathing and showering. When participants returned to the office for the weekly appointments, they were given a new device for the upcoming week.

Tool usage questionnaire

After each intervention session, participants completed an interviewer-administered tool usage survey (Fig. 1). The survey was designed to explore how often participants used the tools throughout the course of the intervention week. Participants rated how often they used specific tools based on response categories with values including 0 (“Never”), 1 (“Once”), 2 (“A few times”), 3 (“Everyday”), and 4 (“Multiple times per day”) for each tool available. A total of 13 tools were available.

Two constructs related to the tools were important: the number of tools taken and the frequency of tool use. The interviewer completed a checklist with participants assessing how many tools were taken to use and how often the tools were used at each time point. The number of tools taken was summed, ranging from 0 to 13. Frequency of tool use was calculated by summing how often any of the 13 available tools were used ranging from 1 (“Once”) to 4 (“Multiple times per day”) across only the tools participants reported using during the intervention weeks. Participants who reported never using any tools were given a zero value on number and frequency of tool use.

Qualitative data: semistructured interviews

Following the interviewer-administered tool-usage survey at the end of each intervention week (Fig. 1), participants took part in a semistructured interview to discuss their experiences during the previous week while working towards the sedentary behavior goal. This study focused only on data from the final interview because it included questions about each of the tools available during the intervention. First, participants were asked “what strategy or strategies helped you the most” and “what tools helped you the most” to explore if there were any strategies or tools outside of the ones provided within the intervention that helped participants with the goal. Then, the interviewer asked participants about each of the tools provided by the research team to see if the participant had tried the tool during the intervention and why or why not. Finally, participants were asked to design a “magic tool” that would help the most with accomplishing the intervention goal. The purpose of these questions was to learn more about what tools might have been especially effective compared with those that were not. Additionally, the interviews were used to explore potential themes related to tool use for the specific behaviors (i.e., sitting less and increasing sit-to-stand transitions).

Mixed-methods data analyses

We used a sequential convergent (QUAN + qual) mixed-methods approach to explore participants’ experience using tools to change sedentary behavior [28, 29]. Using a mixed-methods approach allowed for further understanding regarding not only what tools were effective, but why certain tools were more effective than others and how tool use changed over time throughout the intervention. Mixed-method

analyses aimed to provide a more comprehensive understanding of how participants effectively used tools to change sedentary behavior.

Quantitative analysis

We used separate mixed-effects models, with days nested within participants, to explore the association between changes in number of tools or total tool use, and changes in sitting time or number of *sit-to-stand transitions*. Analyses were stratified by intervention condition, all models adjusted for baseline sitting time or number of *sit-to-stand transitions* depending on the response variable, and all models were conducted in R. Three models were run for each outcome: the first two models explored the changes in number of tools only (model 1) and changes in tool use only (model 2), whereas the third model explored both variables (model 3). Each model included a random intercept to account for clustering among observations within people. We explored using a random slope to account for individual sedentary behavior-change trajectories but these models were not significantly different from the random intercept-only models. The residuals for the *sit-to-stand transition* models were skewed; therefore, the variable was log-transformed in each model.

Qualitative analysis

Following the quantitative analyses, the semistructured interview data were used to further explore participants’ attitudes towards intervention tools and explain the quantitative results; specifically, to further understand how participants achieved behavior change and what aspects of tool use facilitated those changes. Themes relevant to these aims were generated from the content of the interviews to provide greater understanding about the process of change.

A structural coding approach guided the thematic analysis with the interview questions driving how codes were applied to provide a more structured process. Interviews were recorded and the lead author, who has formal training in qualitative and mixed-methods research (M.T.), reviewed each interview to code for content and extract relevant themes. The process began with an initial cycle of open coding to identify segments of data related to tool use. Reviewing the interviews assisted in refining the number of overall codes by grouping them into descriptive categories that were appropriate for final analysis [30, 31]. All interviews were repeatedly reviewed to capture relevant themes and highlight specific phrases to represent key findings. Saturation was determined when no additional information was presented and no new codes were generated from two interviews. To confirm saturation, a final two interviews were coded and no new codes were generated. The data were analyzed using Dedoose

software (SocioCultural Research Consultants, LLC version 7.5.9) by M.T. and interpretations were refined in consultation with the other authors.

Quantitative results

A total of 30 participants were included in the analyses who were primarily female (73 per cent) and White, non-Hispanic (80 per cent) with an average age of 60 (Table 1). For the “*sit less*” condition, the most commonly used tools during the first week were the branded study bracelet, physical timers, and emails; however, in the second week, participants reported using the physical timers less often, but continued to use the bracelet and reminder emails or a standing desk. For the “*sit-to-stand transition*” condition, the tally counter and physical timers were the most popular tools across both weeks. Participants used the bracelet more the first week and reminder emails as a communication medium for prompts were used most during the second week (Table 2). Tool use changed across weeks in both conditions (Table 3), but these changes were not significant.

Results from the mixed-effects regression analyses (Table 4) found a significant relationship between change in the number of tools used and sitting time ($\beta = 22.15, p = .01$), indicating an increase in sitting time of 22.15 min per day on average for a one-tool increase in the number of tools taken (model 1). Additionally, change in total tool use after adjusting for number of tools was significant ($\beta = -12.86, p = .02$), demonstrating that a one-unit increase in tool use was associated with an almost 13 min reduction in sitting time (model 3). This model also showed a significant positive association between change in number of tools and sitting time after adjusting for frequency of tool use ($\beta = 63.70, p = .001$), indicating that increasing the number of tools used without increasing frequency of tool use was associated with more sitting time. There were no significant findings for number of tools or frequency of tool use and *sit-to-stand transitions* (model 2).

Table 1 | Demographic characteristics of Take a Stand pilot intervention trial (N = 30)

Variable name	Mean (SD) or frequency (%)
Age	60.4 (5.9)
Gender	
Female	22 (73)
Male	8 (27)
Body mass index (mg2/kg)	27 (4.7)
Race/ethnicity	
White non-Hispanic	24 (80)
All other	6 (20)
Marital status	
Married	17 (57)
Not married	13 (43)

Table 2 | Number of participants who used the tool each week in both conditions

	<i>Sit less</i> (N = 15)		<i>Sit-to-stand</i> transitions (N = 15)	
	Week 1	Week 2	Week 1	Week 2
Intervention tool				
Participants who used tool [N (%)]				
Standing desk ^a	6 (40)	8 (53)	–	–
Tally counter ^b	–	–	7 (47)	9 (60)
Smartphone applications with reminders to stand	2 (13)	1 (6)	2 (13)	2 (13)
Computer programs with reminders to stand	4 (26)	4 (26)	5 (33)	5 (33)
Watch timer	1 (6)	1 (6)	0	0
Physical timer	8 (53)	3 (20)	6 (40)	6 (40)
Notepad	1 (6)	1 (6)	1 (6)	2 (13)
Bookmark	3 (20)	2 (13)	1 (6)	1 (6)
Text messages	1 (6)	2 (13)	1 (6)	2 (13)
Emails	8 (53)	10 (67)	5 (33)	7 (47)
Phone calls	3 (20)	1 (6)	3 (20)	2 (13)
Study bracelet	9 (60)	7 (47)	7 (47)	5 (33)
Card with study description	2 (13)	3 (2)	1 (6)	0
Dry erase board	0	0	4 (26)	1 (6)

^aOnly working participants in the *sit less* condition were provided with standing desks.

^bOnly participants in the sit-to-stand condition were provided with tally counters.

Table 3 | Descriptive statistics of tool use at intervention weeks 1 and 2 (N = 30)

	Week 1	Week 2	p Value (paired t test)
	Mean (SD)	Mean (SD)	
Sit less group			
Number of tools	3.33 (1.63)	2.93 (1.94)	.38
Frequency of tool use	12.27 (7.5)	12.00 (8.7)	.85
Sit-to-stand transitions condition			
Number of tools	3.07 (1.62)	2.93 (1.83)	.73
Frequency of tool use	10.07 (6.9)	11.60 (7.6)	.37

Qualitative results

A total of 24 interviews were coded and a thematic analysis revealed four overall themes related to how tool use evolved over the course of the intervention including (a) prompts to disrupt behavior; (b) tools matching the goal; (c) tools for sit-to-stand were ineffective; and (d) tool use evolved over time.

Prompts to disrupt behavior. Participants reported that prompts were an effective strategy to change behavior; how participants preferred the prompts to be delivered varied. For some participants, prompts from a computer app or via email were effective because they spent most of their time at a computer which made the prompts accessible. Other participants used physical timers as prompts because they were not always at a computer or near their phone. Smartphone apps were effective for some participants, but others resisted any phone-based prompts because they “didn’t like to be so attached to a phone.” Participants reflected on the usefulness of timers to cue behavior change because

as one participant stated, “reminders are important even if you’re doing something you like.”

Tools matching the goal. The standing desk for the “*sit less*” group was effective and some participants reported that it was all they needed to accomplish the behavior. Participants who opted for the standing desk reported that it was extremely useful in helping them accomplish the goal to *sit less*. According to one participant, once she used the standing desk, she “did not need any additional tools.” In contrast, for participants in the sit-to-stand condition, some participants reported that the computer app timers were ineffective because they prompted participants to stand for extended periods as opposed to simply transitioning from sitting to standing which was the goal of the study.

Tools for sit-to-stand were ineffective. Participants in the “*sit-to-stand transition*” group reported that the majority of tools available were mostly ineffective. For

Table 4 | Results from the mixed-effects regression models exploring the association between change in number of tools and frequency of use with change in sedentary behavior outcomes (i.e., sitting time and *sit-to-stand transitions*) across intervention weeks stratified by condition

		Daily minutes of sitting time (n = 15)			Daily number of <i>sit-to-stand transitions</i> (n = 15)		
		Coefficient	SE	p Value	Coefficient	SE	p Value
Model 1	Number of tools	22.15	8.43	.010	0.015	0.031	.617
Model 2	Tool use frequency	3.19	2.36	.178	0.005	0.006	.433
Model 3	Number of tools	63.70	19.28	.001	0.007	0.048	.884
	Tool use frequency	-12.86	5.40	.019	0.004	0.011	.730

Models adjust for baseline values of sitting time or *sit-to-stand transitions*, respectively.

SE standard error.

example, participants were satisfied with the timers, but were frustrated by the frequency with which they continued to have to set the timer. Specifically, if participants wanted to achieve the goal of adding an additional 30 *sit-to-stand transitions* per day, they would need to set a timer to prompt them approximately every 20 min. For some participants, this was burdensome and unrealistic. Additionally, for participants who tried the electronic counter, some participants reported frustration with the device because not only were they required to set a timer to remind themselves to stand up, but they also needed to remember to count the stand by pressing the counter. Ultimately, it was too many tasks to remember and participants were frustrated with the amount of work required. Also, although the device itself was on a small lanyard, the lanyard length was too small to allow participants to wear it as a necklace and too big to wear around the wrist; this prevented participants from fully integrating the tool into their daily lives.

Tool use evolved over time. Some participants reported taking too many tools in the first week and not using most of them. When they identified a tool that worked, they used that tool more frequently during the week and did not need to use any additional tools. Additionally, participants reported that tools that worked in certain environments were not effective in other environments. For example, computer prompts were helpful while at work, but participants needed to use a different tool to work on the behavior at home. Participants also discussed that tools needed to be convenient and fit into their daily routines. Some participants liked the physical timers, but did not feel comfortable using them in all situations. Participants who worked in an office setting did not want to use the timers because the noise might disrupt other coworkers.

Magic tool. There were a variety of responses when participants were asked to design the “magic” tool to help them change their behavior. Some participants wanted the ActivPAL itself to vibrate as a prompt to stand up (which is now available in some models) while others preferred a wrist-worn device.

Several participants envisioned an “ejecting chair” or some device that would physically force people out of the chair and into a standing position. One participant would have even opted for an electric shock as a reminder to stand. A television prompt that would pop up while watching a show to remind participants to stand was also an option. Several participants wanted the magic tool to provide feedback regarding progress. Getting real-time feedback from a device that was always with them would be especially helpful because “it’s important to be reminded all day long.” Therefore, participants wanted a tool that would work in all environments to make it easier to work on the goal continuously throughout the course of the day.

DISCUSSION

With the evidence surrounding the negative effects associated with sedentary behavior, new interventions to reduce and interrupt sitting time have become an important public health focus. By combining qualitative and quantitative strategies in a mixed-methods approach, this study adds breadth and depth to help elucidate the context behind successful tool use to change sedentary behavior [32]. The present study is the first to conduct a more thorough analysis of participant tool use specific to a sedentary behavior intervention that featured two distinct behaviors (i.e., sitting less and increasing *sit-to-stand transitions*). A mixed-method analyses allowed for further exploration into understanding not only if (i.e., quantitative results) tool usage affected outcomes, but why (i.e., qualitative feedback).

Based on the quantitative analysis, participants who used fewer tools, but used those tools more frequently were better able to reduce their sitting time. Furthermore, participants who increased number of tools without increasing frequency of tool use had an additional 63 min of sitting time. This result could be based on participants who were unable to identify an effective tool and were therefore struggling to change their behavior. After exploring the qualitative data, the reasoning behind this relationship became more evident. Participants who were

successful with reducing their sitting time reported that they did not need multiple tools; instead, they tended to rely on one tool and use that tool to work on the goal. However, it was difficult for participants to predict which tools would be most effective before trying out the behavior; therefore, providing a menu of tools to choose from was especially important. Given the novelty of the behavior, participants needed to experiment with tool options before honing in on which tool would be the most effective for them.

Tool use and preference varied dramatically across participants and across environments. Although participants liked using prompts, how those prompts were delivered differed. Some participants preferred physical timers while others only needed a computer prompt to remind them to stand while others relied on their smartphones. Providing different options is important to ensure participants find a method that works the best for them. Going forward, a tool that could be worn continuously (i.e., wearable device) might be especially valuable because participants would have access to the tool in all situations which would allow them to continuously work on the behavior change. This result further justifies a recommendation from a recent review by Martin et al., which recommended developing technologies that allow people to monitor their sedentary behavior to support them in sitting goals [14]. The Take a Stand pilot was the first study to explore *sit-to-stand transitions* as a specific behavior-change goal. Based on feedback from participants, current tools available to change this behavior were lacking in utility and were generally ineffective. Prompts available for sedentary behavior specifically focus on displacing sitting with more prolonged standing and are inappropriate for increasing the number of *sit-to-stand transitions* which would break up sitting more frequently. Additionally, given the high number of transitions participants need to achieve throughout the day to shorten prolonged sitting bouts (e.g., every 20 min), trying to monitor this behavior continuously is extremely taxing. The electronic counters provided by the study were irritating for participants because they could not fit them into a daily routine. Having to remember to record the transitions was also a deterrent to using these tools. Although the ActivPAL feedback provided during the health education sessions was helpful for participants, this information was not provided real-time and the feasibility of using an ActivPAL long-term is unclear based on costs (if participants kept devices more devices would be needed per study and each device is costly) and wearability (some participants may experience skin irritations from the thigh adhesives). It is unclear what types of tools will be most effective in targeting this behavior. Previous studies have shown that self-monitoring and goal-setting are key constructs

[17, 18]. Therefore, future sedentary behavior tools should not only monitor amount of sitting time, but also record the number of *sit-to-stand transitions* to test this as a mechanism to affect biological outcomes.

Strengths and limitations

The strengths of this study include the combination of methods to explore which tools were helpful and why for changing sedentary behavior. Given the recent surge in interventions to change sedentary behavior [14, 15], a thorough exploration into how tools can be used to target important behavior-change constructs, specifically, self-monitoring and cues, is especially valuable and can provide information for future intervention development. Limitations of the current study include a small sample size of mostly White, non-Hispanic females. Additionally, because we wanted to target both working and nonworking adults, our sample of participants aged 50 to 70 years may not generalize to the population of older adults at large. Another limitation is our tool use questionnaire only provided information about number of tools and frequency of tool use; the survey did not ask about functionality of these tools to help participants their change behavior. Future studies should explore long-term tool-use satisfaction in a larger population of more diverse individuals to increase generalizability.

Conclusions

Based on the review by Prince et al., it is clear that to effectively change sedentary behavior, specific interventions must be designed with a sole focus on interrupting sitting time [13]. A major limitation for intervening is that sedentary behavior is innately habitual. Research has shown that changing habitual behaviors may require even more cues than nonhabitual behaviors and it is still unclear what types of tools are the most effective for changing sedentary behavior [33]. Participants in the current study relied on prompts and cues to remind them to work towards the goal. It could be that participants need additional support from multiple tools early in the intervention when they are first working on the behavior change; however, once they have a better understanding about how to change the behavior, the reliance on these tools may decline. Future interventions should provide participants with an array of tools to choose from while they hone in on the tool that works the best for them given their specific needs. Another benefit of providing participants with a menu of tools is that different tools may be more effective in different environments. For example, although standing desks were a popular tool for working individuals, these devices only work for part of one's daily routine. Therefore, tools need to transition from work to home to help individuals continue to work towards the goal across a variety of environments.

Compliance with Ethical Standards

Funding: This study was funded through pilot funds from the Department of Family Medicine and Public Health at the University of California, San Diego. The analyses and conclusions presented here are those of the authors and do not reflect those of the funders.

Conflict of Interest: None declared.

Authors' Contributions: Designed and delivered the original study: M.T., D.E.R., and J.K. Analyzed the data: M.T., S.G., L.N., and J.K. Wrote the manuscript: M.T., S.G., D.E.R., C.N., H.M., L.N., J.N., and J.K. All authors read and approved the final manuscript.

Primary Data: All authors have contributed and reviewed the proposed manuscript. The manuscript has not been published or submitted elsewhere and it does not contain data that are currently submitted or published elsewhere. Additionally, the authors have full control over all the primary data and agree to allow the journal to review the data if requested.

Ethical Approval: Ethics approval was granted by the Human Research Protections Program of the University of California, San Diego (Protocol #130817).

Informed Consent: Participants provided written informed consent.

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