The Effect of an Acute Sedentary Behaviour Reducing Intervention on Subjective Well-Being among University Students: A Pilot Randomized Trial

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ABSTRACT

Background: The effect of sedentary behaviour (SB) on subjective well-being (SWB), particularly through a SB-reducing intervention largely remains unknown. This pilot trial examined whether an acute intervention designed to reduce SB would enhance SWB in a sample of university students.

Methods: A three-week (i.e., baseline, intervention, follow-up) randomized controlled pilot trial was conducted. Thirty-two sedentary university students were randomized to an acute behavioural counseling intervention ($n = 17$) or control group ($n = 15$). Behavioural counseling grounded in the health action process approach aimed at reducing daily SB for 1 week. Device-measured outcomes (i.e., steps, standing, sitting, sit-to-stand transitions), self-reported SBs (i.e., self-compared, domain-specific), and SWB measures (i.e., affect, life satisfaction, subjective vitality, overall SWB) were assessed weekly.

Results: Repeated-measures ANOVAs revealed non-significant medium-to-large effects for self-reported SBs (i.e., $0.116 \leq \eta_p^2 \leq 0.253$), device-measured standing time (i.e., $\eta_p^2 = 0.161$), and life satisfaction and overall SWB (i.e., $0.141 \leq \eta_p^2 \leq 0.178$) favouring the treatment group over the control group.

Conclusions: Overall, this acute intervention was ineffective in reducing SB among university students. Comparatively to previous acute SB-inducing interventions, results suggest that SB-reducing interventions may require more robust treatment application than the current pilot study. Strategies such as prompts/cues, repeated intervention delivery, and longer intervention periods are recommended. Strategies that promote larger non-convenient sampling (e.g., longer recruitment periods) also are recommended. Taken together, these strategies will increase treatment effects and statistical power of subsequent intervention trials.

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INTRODUCTION

Sedentary behavior (SB) describes any behavior that is (i) waking, (ii) has an energy expenditure of ≤ 1.5 metabolic equivalents, and (iii) is performed in a sitting, lying, or reclining posture (Tremblay et al., 2017), and encompass the vast majority of behaviors performed in nearly every domain of daily life. Given that most individuals spend the bulk of their waking time engaged in SBs (Colley et al., 2011), particular focus has been devoted to studies investigating the health consequences of excessive SB, such as heart disease, type 2 diabetes, hypertension, some cancers, and all-cause mortality (De Rezende et al., 2014). Notably, relatively fewer studies have examined SB and health through a salutogenic lens, whereby health encompasses “positive health conceptions, such as quality of life, flourishing, and well-being” (Mittelmark & Bauer, 2017). One salutogenic outcome of particular interest is subjective well-being (SWB).

Subjective well-being, as defined by Diener et al., is “a broad category of phenomena that includes people’s emotional responses, domain satisfactions, and global judgements of life satisfaction”, which is assessed through outcomes of affect (positive and negative) and life satisfaction (1999). This operationalization of SWB by Diener et al. (1999), is considered hedonic well-being, whereby optimal SWB is attained through maximizing happiness (Ryan & Deci, 2001). An interfacing conceptualization of SWB is eudaimonic well-being, whereby optimal SWB is attained through fulfillment of purpose and self-realization (Huta, 2015).

Previous works examining the relationship between SWB and SB demonstrate mixed results. (Hogan et al., 2015; Wrosch & Sabiston, 2013). Results from experimental studies suggest that greater SB results in lower positive affect (Duvivier et al., 2017), greater negative affect (Edwards & Loprinzi, 2016; Endrighi et al., 2016), and lower life satisfaction (Edwards & Loprinzi, 2017). However, all of these studies experimentally increased SB, in that participants in the treatment group were encouraged to sit more and move as little as possible for a period of four days (Duvivier et al., 2017) to two weeks (Endrighi et al., 2016). Additionally, experimental works examining SB and SWB have not consistently measured SB as is currently defined (Tremblay et al., 2017), instead using accelerometers (Endrighi et al., 2016) or step counters (Edwards & Loprinzi, 2016, 2017) as a proxy for SB. Issues with previous works are further confounded when considering their lack of measurement of domain-specific SB. Domain-specific SB, or the SB accumulated in different contexts of sitting (e.g., sitting during meals, occupation, screen time, etc.), demonstrate stronger, and often opposite, associations (i.e., r s) with outcomes of SWB than total SB (O’Neill & Dogra, 2016). Thus, measurement of domain-specific sitting may reveal unique relationships with outcomes of SWB, independent of total sitting.

Overall, previous work has been limited by either cross-sectional design, solely increasing SB, invalid measurement of SB, and/or lack of delineation between total and domain-specific sitting behaviors. Hence, there is the need for a study that experimentally decreases SB and assesses device-measured and domain-specific SB to evaluate the effect of SB on outcomes of SWB. Notably, the use of explicit behavioral theory is absent among SB-inducing studies. One such theory is the Health Action Process Approach (HAPA; Schwarzer, 2008). The HAPA delineates individuals’ behaviour change status into three stages: preintenders, intenders, and actors, with specific constructs predicting and mediating progression through the stages. Most notably, the HAPA postulates that action and coping planning mediate the ‘gap’ between intention and behaviour (i.e., action). Application of the HAPA model in health behaviour change has been used to predict the adoption and maintenance of physical activity (Aliabad et al., 2014; Lippke et al., 2005) and dietary behaviours (Y. P. Duan et al., 2017). With respect to SB specifically, the HAPA model for behavior change has shown suitability and has shown success in increasing break frequency among a sample of university students (Sui & Prapavessis, 2018) and increasing non-SBs among office workers (Rollo & Prapavessis, 2020).

Therefore, a randomized pilot trial was conducted to experimentally explore whether an intervention designed to decrease SB will lead to improvements in SWB. The main objective of this trial was to determine the preliminary effectiveness of an acute HAPA-based behavioral intervention to decrease SB and increase SWB among sedentary university students, in order to inform a future randomized controlled trial. A secondary objective of this trial was to explore whether any changes in SB outcomes would be related to changes in outcomes of SWB.

METHODS

Trial reporting is guided by the CONSORT 2010 Statement for reporting randomized control trials (Moher et al., 2012). A completed CONSORT checklist can be found in *Supplementary Material 1*.

TRIAL DESIGN/ETHICS

A three-week (baseline, intervention, post-intervention), single-blinded, parallel-group (equal allocation ratio [1:1]), randomized-controlled pilot trial was conducted. No changes to trial protocol, eligibility criteria, or planned statistical analyses were made after trial commencement. Ethics approval for the study was obtained from the host institution’s REB (Project ID: 112399).

PARTICIPANTS/RECRUITMENT

A convenience sample of university students from the host institution were recruited to participate in this study

through posters distributed around university campus, verbal advertisement during lectures, and through online university groups on Facebook. Eligible participants (a) were full-time university students attending the host institution, (b) aged 18 years of age or older, (c) who were able to read and write in English, (d) had access to a computer/smartphone with internet, and (e) recorded ≥ 7 hours of sedentary time per day over the baseline week, via ActivPAL4 inclinometer. The cut-off time of seven hours of sedentary time per day was based off meta-regression findings regarding self-reported SB by Po-Wen and colleagues (Ku et al., 2018). Exclusion criteria were (a) part-time enrollment or currently on a leave of absence from full-time studies at university, (b) individuals self-reporting a mental illness, and (c) individuals currently reporting a physical disability that would prevent them from walking.

SETTING/DATA COLLECTION PERIOD

The study took place at a mid-sized (~30,000 students) post-secondary institution in Ontario, Canada during the 2019–2020 academic year.

INTERVENTION TREATMENT

Participants randomly allocated to the intervention group were told they would receive a single theory-driven behavioral counseling session, with the goal of co-developing strategies aimed at (1) decreasing their weekly SB by 1–2 hours, as well as (2) increasing their daily step count to $\geq 10,000$ steps/day, over the next week.

Participants were initially prompted to think about strategies to reduce their SB and increase steps/day, followed by the researcher stating: “strategies that we come up with should be specific, so that you’re not thinking about when, where, or how you’re going to do them, or who you’re going to do them with. Strategies also should be realistic *for you*, because if *you* don’t find them realistic, you’re probably not going to do them”. Participants were then asked if they had any strategies that they could immediately think of. Prompts for behavioral strategies were used if the participant could not think of any strategy, and generally revolved around reducing SB in a particular domain of SB (e.g., transportation, occupation, etc.).

Creation of behavioral strategies was guided by the FITT principle (Burnet et al., 2020), adapted to a SB context; where F represented the frequency per week that a strategy would be enacted (e.g., 3–4 times per week [Monday, Wednesday, Friday], every hour of sitting); I represented the intensity/length of time that a strategy be performed for (e.g., 20 minutes, 5-minute break from sitting, 3000 steps); the first T represented the time of day that the behavior would be performed (e.g., 6PM, mornings [8–11], during studying); and the

second T represented the type (i.e., modality) of behavior performed (e.g., standing, walking, weightlifting).

Upon creation of a strategy and its FITT specifics, an accompanying coping strategy (or strategies) was prompted via the researcher stating: “With any new strategy that we may try and implement, there are inevitably barriers that would prevent us from enacting the strategy. Can you think of any barriers or reasons that you might not perform this strategy? What could you do or plan for so that you could still perform the strategy, despite these barriers?”. Coping strategies often focused on practical steps, like setting an alarm or reminding a friend to work out together. Proceeding creation of a complete strategy, participants were asked if they thought the strategy was specific and realistic enough as a fidelity check. Upon agreement, participants were prompted to think about any other strategies that could help them achieve the SB and step count goals for the next week. Strategies also often included using the native step counter app on their smartphone (e.g., Health on iOS, Google Fit on Google devices) to self-monitor their daily step count. At the end of the session, participants were encouraged to try each strategy at least once, and to try to adjust strategies if unperceived barriers arise. Additionally, participants were advised to place the completed counseling form somewhere where they would regularly see it. On average, participants co-developed 3–4 strategies. Behavioral counseling session typically took 30–45 minutes and were delivered face-to-face by the researcher in the researcher’s lab.

Behavioral counseling was guided by the HAPA (Schwarzer, 2008) with associated intervention behavior change techniques labelled as (1.1) Goal Setting (behavior); (1.2) Problem Solving; (1.4) Action Planning; (1.5) Review behavior goal(s); (1.9) Commitment; (2.3) Self-monitoring of behaviors; and (7.1) Prompts and cues, according to the Michie et al., (2013) behavior change taxonomy. Prior application of the HAPA model and the aforementioned behavior change techniques to manipulate SB in this population has also been utilized in previous work (Sui & Prapavessis, 2018).

Control

Participants randomly allocated to the control group received no specific instructions to modify their behavior. If prompted for further instruction, the researcher would encourage the participant to continue their normal behavior.

PRIMARY OUTCOMES

Device-measured SB/PA

The ActivPAL4 inclinometer (PAL Technologies, 2020) was used to track the device-measured PA and SB of participants. A 7-day 24-hour continuous wear protocol was used. The ActivPAL4 was attached to the center of the right thigh, halfway between the superior iliac spine

of the hip and the patella (Edwardson et al., 2017). Participants did not take off the device during bathing or water-based activities. Given the 7-day 24-hour wear protocol, a minimum of 6 valid days (i.e., 144 hours) of wear time was deemed necessary to be included in analysis to be representative of the week. Collected data were visualized through graphs and scanned for abnormalities (e.g., excessively large volumes or high intensities of activity). Outcomes derived from the ActivPAL4 device included: average daily steps (steps per day); average daily standing time (minutes per day); average daily stepping time (minutes per day); average daily sitting time (minutes per day); and average daily sit-to-stand transitions (transitions per day).

Self-reported SB

Past 7 days self-compared SB (i.e., sitting, break frequency, break duration) was assessed through three items on a 5-point Likert scale (“In the last 7 days...”), with a score of 1 indicating *Much less than normal*, 3 indicating *About the same*, and 5 indicating *Much more than normal*.

Past 7 days domain-specific SB was assessed using the modified SIT-Q 7d questionnaire (Sui & Prapavessis, 2016). The original SIT-Q 7d instrument (Wijndaele et al., 2014) is a self-reported questionnaire that measures weekday (WY) and weekend (WD) time spent sitting in various activities in a number of domains of activity over the past 7 days (i.e., sleep and naps, meals, transportation, screen time, occupation(s), and other activities). A sample questionnaire can be found in *Supplementary Material 2*. Domain-specific SB question options were recoded to represent the upper limit (i.e., more sedentary) of that option, in order to signify the most conservative estimate of SB (e.g., ‘15–30 min recoded to 0.5 hours).

Past 7 days total weekday SB was assessed through a single question on the International Physical Activity Questionnaire – Short Form 7 days (IPAQ-S7S; Craig et al., 2003). Participants were asked to specify both an hour(s) per day and minute(s) per day estimate. A total weekly sitting estimate was calculated by multiplying responses by seven.

Outcomes of SWB

Past 7 days positive and negative affect was assessed through the Positive and Negative Affect Schedule (PANAS; Watson et al., 1988). Separate scores (range: 10–50) for positive and negative affect are attained by summing items assessing positive and negative affect, respectively.

Life satisfaction was assessed through the Satisfaction with Life Scale (SWLS; Diener et al., 1985). A total score (range: 7–35) is attained by summing the responses, with higher scores representing higher life satisfaction.

Eudaimonic well-being was assessed through the Subjective Vitality Scale (SVS; Ryan & Frederick, 1997). A shorter, more validated, six question version of the SVS developed by Bostic, Rubio, & Hood was used in the present work (Bostic et al., 2000).

Overall SWB was assessed through the Warwick-Edinburgh Mental Well-Being Scale (WEMWBS; Tennant et al., 2007). A total score (range: 14–70) is attained by summing the responses, with higher scores representing greater subjective well-being.

OTHER OUTCOMES

Demographics were assessed through a single item (e.g., “What is your...”); age, preferred gender, current program of study, current year of study, degree pursuing, and ethnicity were collected. Past 7 days physical activity was assessed using the IPAQ-S7S (Craig et al., 2003). A total weekly activity score for each physical activity intensity was attained through the product of how many days that exercise was performed, and average hours spent in performing said intensity of exercise.

PROCEDURE

Interested participants met with the researcher, who presented the detailed letter of information and consent and collected consent. Consenting participants then completed the demographics questionnaire and then were fitted with the ActivPAL4 inclinometer. Participants then scheduled their second visit for seven days after the initial meeting. At the beginning of the second visit, the ActivPAL4 was removed and SB levels for inclusion were verified. Upon confirmation of eligibility, participants were assigned to either the treatment or control group. Participants then completed the online questionnaires, beginning with the self-compared sitting questions, and followed by the modified SIT-Q 7d questionnaire, IPAQ-S7S, PANAS, the SWLS, the SVS, and the WEMWBS. After the questionnaires, participants in the treatment group received the single session of behavioral counseling, while those in the control group received no behavioral instructions. Participants in both groups were then refitted with a new ActivPAL4 device and scheduled their third visit for a week later. During the third visit, the ActivPAL4 device was removed and both groups completed the questionnaires for the second time. Afterwards, a new ActivPAL4 device was refit and participants were given no specific behavioral instructions (treatment group participants were told to “do whatever you want” if the researcher was asked for instructions), and the fourth visit was scheduled for a week in the future. During the fourth visit, ActivPAL4 devices were removed from participants, and all participants completed the questionnaires for the third time. A researcher then debriefed all participants. Participants received a \$30 gift card for their participation.

REQUIRED SAMPLE SIZE

Due to the pilot nature of the present trial, no formal sample size calculation was used. Rather, the sample size of previous acute SB intervention studies was used as a guideline for sample size (Duvivier et al., 2017; Edwards &

Loprinzi, 2017). Hence, a sample size of 30 was deemed appropriate for an initial pilot.

RANDOMIZATION

Block randomization was used to allocate participants to either intervention or control groups in a 1:1 ratio with a fixed block size of 36 participants (i.e., 18 intervention and 18 control, accounting for a 20% attrition rate based on a previous intervention in this population; (Sui & Prapavessis, 2018). The random number sequence was generated through the list randomizer on RANDOM.org (RANDOM.org, 2020). Allocation was not concealed to the researchers. The same researcher generated the random allocation sequence, enrolled participants, and assigned participants to groups.

BLINDING

Participants were blinded to the intervention content and assignment. The study was advertised as a “behavior change study” in recruitment materials, in the letter of information/consent, and in participant correspondence.

STATISTICAL ANALYSIS

Independent-samples *t*-tests were used to compare baseline demographic characteristics and primary outcome variables between groups to determine adequate group randomization. A series of 2 (treatment vs. control) $\times$ 3 (time: visit 2, visit 3, visit 4) repeated measures ANOVAs were used to identify any time by group interaction effects and was accompanied by partial eta squared (η_p^2) and observed power values. Bivariate correlations (absolute and residual change) were computed for intervention-baseline differences (i.e., visit 3 – visit 2) between SB outcomes and outcomes of SWB to affirm relationships between these outcomes. For certain device-based SB measures (i.e., average daily standing time, average daily stepping time, average daily sitting time, and average daily sit-to-stand transitions), interaction effects and correlations were calculated using the percentage of the waking day these behaviours were performed (e.g., percent of the waking day spent sitting). Analysis was computed using IBM SPSS software (version 23). Statistical significance was set at .05. Partial eta squared, confidence intervals, and statistical power accompanied all *p* values. In line with Bakeman (2005), partial eta squared values of 0.02, 0.13, and 0.26 represented small, medium, and large effect size statistics for repeated measure designs.

DATA IMPUTATION

A Winsorization technique was applied to the data; data points over the 95th percentile and underneath the 5th percentile in each group were replaced with the value of the 95th percentile and 5th percentile, respectively. Winsorization

has demonstrated validity as a method for dealing with outliers (B. Duan, 1998). A total of 63 data points (1.00% of possible data points) were imputed this way.

RESULTS

SAMPLE CHARACTERISTICS

Missing Data

Two participants who were assessed for eligibility were excluded. One participant was excluded for not meeting the SB inclusion threshold (i.e., reported <7 hours/day of SB), while the other participant chose not to participate citing the time commitment. Flow of participants and dropouts is shown in *Figure 1*.

Recruitment

Participants were recruited during the Fall 2019 and Winter 2020 academic terms at the host institution (i.e., September 2019 to February 2020). The study was stopped after planned sample size of completed participants was reached.

Group Equivalency

Sample characteristics are presented in *Table 1*. Significant group differences at baseline were observed for average daily steps, average daily stepping time, WY sleep time, and WY napping, whereby the treatment group reported significantly higher in all outcomes (*ps* > 0.05). For these variables, baseline scores were input as covariates to account for differences at baseline. No other significant differences between groups at baseline were found.

Descriptive Data

Descriptive data for device-measured SB outcomes are presented in *Table 2*. Descriptive data for self-compared SB, average weekday sitting are presented in *Table 3*. Descriptive data for domain-specific SB and outcomes of SWB are presented in *Supplementary material 3* and *Table 4*, respectively.

INTERACTION EFFECTS AND MAIN EFFECTS

Interaction effects and main effects for device-measured SB outcomes are presented in *Table 5*. Overall, no device-measured SB outcome demonstrated a significant interaction effect; however, a significant main effect for average daily standing time was observed (*p* = 0.004), indicating that both groups increased their percentage of stepping time during their day from baseline to intervention and then returned to baseline levels post-intervention.

Interaction effects and main effects for self-compared SB outcomes are presented in *Table 5*. Overall, no self-compared SB outcome demonstrated a significant interaction effect. Additionally, a significant main effect for self-compared break frequency was observed,

Figure 1 Flow of participants through the study.

indicating both groups perceived an increase in their break frequency from baseline to intervention and then a drop back to baseline post-intervention.

Interaction effects and main effects for self-reported domain-specific SB are presented in *Supplementary material 4*. Overall, only WY sleep [$F(1, 28) = 5.135$, $p = 0.031$] and average number of breaks from other activities demonstrated a significant interaction effect [$F(2, 28) = 4.737$, $p = 0.017$]. This corresponded to an increase in sleep time for the treatment group and decrease in sleep time for the control group from intervention to post-intervention and both groups decreasing their number of breaks from baseline to intervention, but only the treatment

group increasing their other activities break frequency back to baseline levels post-intervention. Significant main effects ($p \leq 0.05$) were also observed for WD napping, WY lunch, total weekly transportation, student break duration, WY and WD TV, WD computer/smartphone use, screen time break frequency and duration, and other activities break frequency. For WY lunch, total weekly transportation, WY/WD TV, and WD computer use, this was associated with both groups decreasing these SBs from baseline to post-intervention. For break frequency and duration measures, this was associated with a decrease in break frequency and break duration for both groups from baseline to post-intervention.

	<i>M (SD)</i>
Age	19.45 (2.68)
Gender	<i>n (%)</i>
Men	12 (38.7)
Women	19 (61.3)
Year of Study	<i>n (%)</i>
First Year	13 (41.9)
Second Year	11 (35.5)
Third Year	2 (6.5)
Fourth Year or Higher	4 (12.9)
Missing	1 (3.2)
Current Degree Pursuing	<i>n (%)</i>
Undergraduate	30 (96.8)
Doctorate or Professional degree	1 (3.2)
Current Program of Study	<i>n (%)</i>
Engineering	2 (6.5)
Health Sciences	19 (61.3)
Information and Media Studies	2 (6.5)
Science	5 (16.1)
Social Sciences	2 (6.5)
Business and Finance	1 (3.2)
Ethnicity	<i>n (%)</i>
European/Caucasian	7 (22.6)
Canadian	2 (6.5)
Hispanic	1 (3.2)
Asian	14 (45.2)
Black	3 (9.7)

Table 1 Demographic Characteristics (*n* = 31).

Interaction and main effects for SWB outcomes are presented in **Table 5**. Overall, no outcome of SWB demonstrated a significant interaction effect.

RESIDUAL CHANGE AND ABSOLUTE DIFFERENCES CORRELATIONS

Correlations between change in device-measured SB outcomes and change in outcomes of SWB are presented in **Table 6**. Change in average daily standing time was significantly correlated with absolute change in overall SWB ($p \leq 0.05$). Correlations between change in self-compared and average weekday SB outcomes and change in outcomes of SWB are presented in **Table 7**. Residual change in self-compared weekly break frequency was significantly positively correlated with life satisfaction and overall SWB ($ps \leq 0.05$). Change in self-compared weekly break duration was significantly

positively correlated with residual change in life satisfaction, as well as absolute change in positive affect, life satisfaction, subjective vitality, and overall SWB ($ps \leq 0.05$). Significant negative correlations were observed between change in average weekday sitting and both residual change and absolute change in life satisfaction ($ps \leq 0.05$). Correlations between change in domain-specific SB and change in outcomes of SWB are presented in *Supplementary Material 5*. Notable significant domain-specific correlations included sleep, screen time, other activities, and breaks from sitting ($ps \leq 0.05$).

ADVERSE EVENTS

Given the minimal risk associated with the intervention and subsequent behaviors, data regarding adverse events/harms were not formally collected. However, anecdotally, no participants noted any adverse events or harms.

DISCUSSION

INTERVENTION EFFECTIVENESS – SEDENTARY BEHAVIOR

Overall, the intervention was unable to significantly decrease device-measured SB, relative to the control group. Low observed power statistics provide evidence that the trial was underpowered to observe changes in these device-measured SB outcomes. However, a medium-sized effect size for average daily standing time was observed ($\eta_p^2 = 0.161$). An informal sample size calculation suggests that a sample size of 60 participants would be necessary to see significant changes in device-measured average standing time. In contrast to device-measured SB, the effect of the intervention on self-reported SBs was more encouraging. For self-compared SB, specifically, consistent medium-sized interaction effects that favoured treatment were observed (i.e., $0.140 \leq \eta_p^2 \leq 0.183$). Similarly, self-reported average weekday sitting and several domain-specific SBs demonstrated medium-to-large effect sizes (i.e., $0.116 \leq \eta_p^2 \leq 0.253$) in favor of the treatment group. Average number of breaks from sitting during other activities, in particular, showed a significant interaction effect in favor of the treatment group, indicating that the treatment group took more breaks from other activities (e.g., hobbies, reading) than the comparison group. These findings highlight the disparity between how sedentary university students perceive they are and their actual device-measured behaviour (Castro et al., 2020), as well as potential self-report bias among the intervention group.

The (lack of) effectiveness of the current SB-reducing intervention presents a stark contrast to the effectiveness of previous SB-inducing studies. Compared to the effectiveness of previous SB-inducing studies like Endrighi and colleagues (i.e., 31.48 min/day increase in sitting time, 95% CI: [-57.64, -5.32]; 2016), or Duvivier and colleagues

TREATMENT (n = 17)				CONTROL (n = 14)		
TIME	MEAN	SD	95% CI	MEAN	SD	95% CI
Average Daily Steps (steps/day)						
Baseline	9252.54	1925.78	[8262.40, 10242.78]	7328.67	2325.12	[5986.18, 8671.15]
Intervention	11028.20	2836.38	[9569.87, 12486.53]	8485.20	3020.25	[6741.36, 10229.05]
Follow-up	9689.50	2714.05	[8294.06, 11084.93]	7478.33	2969.84	[5763.59, 9193.06]
Average Daily Standing Time (minutes/day)						
Baseline	188.74	47.03	[164.56, 212.92]	189.06	62.63	[152.90, 225.22]
Intervention	192.32	41.25	[171.12, 213.53]	190.55	60.23	[155.77, 225.32]
Follow-up	189.81	53.64	[162.23, 217.39]	216.70	72.45	[174.87, 258.53]
Average Daily Stepping Time (minutes/day)						
Baseline	108.75	24.42	[96.20, 121.31]	85.53	22.48	[72.55, 98.51]
Intervention	125.31	33.79	[107.93, 142.68]	96.50	30.70	[78.78, 114.23]
Follow-up	112.54	31.35	[96.42, 128.66]	89.00	31.91	[70.58, 107.42]
Average Daily Sitting Time (minutes/day)						
Baseline	660.11	80.26	[618.84, 701.37]	731.20	92.96	[677.52, 784.87]
Intervention	655.57	83.80	[612.48, 698.66]	722.96	105.47	[662.06, 783.86]
Follow-up	651.36	81.78	[609.31, 693.41]	707.85	71.69	[666.46, 749.24]
Average Daily Sit-to-Stand Transitions (number/day)						
Baseline	50.31	14.20	[43.01, 57.61]	44.79	13.87	[36.78, 52.80]
Intervention	48.84	11.99	[42.67, 55.00]	43.22	12.56	[35.97, 50.48]
Follow-up	49.43	11.99	[43.26, 55.59]	45.04	13.80	[37.07, 53.01]

Table 2 Means, standard deviations, and 95% confidence intervals for device-measured sedentary behaviors throughout the study.

Note: Bold text indicates significant differences between groups at baseline ($p < 0.05$).

(e.g., +5.9 hours/day increase in sitting time, 95% CI: [5.75, 6.05]; 2017), the present work observed a modest 6.21 min/day (95% CI: [-23.19, 35.61]) decrease in sitting time for the treatment group over a 1-week intervention. Despite the contrast in effectiveness between the present work and prior SB-inducing work, comparisons between the two are misleading and inappropriate. Firstly, the present study used inclinometry to measure SB, compared to the use of accelerometers in the previously mentioned work to measure ‘sedentary time’ (i.e., physical inactivity), which cannot distinguish between sitting and standing nor sensitive enough to capture postural changes (Koster et al., 2016). Secondly, inducing SB likely warrants a different approach to intervention than reducing SB given the habitual nature of SB, as behavior modification through rewarding/reinforcing the habit behavior are less likely to encounter traditional barriers to behavior change (e.g., motivation, self-efficacy; Rothman et al., 2011). As the current work recruited already sedentary individuals – a sample with a strengthened SB habit (i.e., ≥ 7 hours/day) – it is likely that the reflective, motivational constructs involved in behavioural initiation process of being less sedentary (e.g., self-efficacy, outcome expectancies, intention) were

not strong enough to counter the developed, automatic habit of SB. Finally, as the present study was advertised as simply a “behaviour change study”, it is unlikely that the participants recruited necessarily had a pre-existing intention to change their SB. Intention is hypothesized to be the strongest predictor of behaviour during the motivational phase of the HAPA (Schwarzer, 2008); hence the effectiveness of an intervention targeting action and coping planning (i.e., post-intentional constructs) may have been limited.

There are several modifications that may improve the effectiveness of the present intervention to reduce device-measured and self-reported SB. Inclusion of components of previously successful SB interventions, such as prompts and cues, can address the lack of cognitive awareness associated with habitual behaviors, like SBs. Specific to the current intervention, the behavioural counseling was likely too brief for the action and coping plan to remain salient to participants, despite attempting to trigger an environmental cue via hanging the action plan in a high-trafficked location. The use of a brief daily prompt (e.g., via SMS) may have triggered the reflective processes needed to reduce SB. Similarly,

TIME	TREATMENT (n = 17)			CONTROL (n = 14)		
	MEAN	SD	95% CI	MEAN	SD	95% CI
Self-Compared Weekly Sitting						
Baseline	3.47	0.62	[3.15, 3.79]	3.29	0.91	[2.76, 3.81]
Intervention	2.82	1.13	[2.24, 3.41]	3.50	0.76	[3.06, 3.94]
Follow-up	3.18	0.81	[2.76, 3.59]	3.21	1.12	[2.57, 3.86]
Self-Compared Weekly Break Frequency						
Baseline	2.94	0.83	[2.52, 3.37]	2.79	0.70	[2.38, 3.19]
Intervention	3.89	0.34	[3.72, 4.07]	2.86	1.03	[2.26, 3.45]
Follow-up	3.29	0.77	[2.90, 3.69]	2.64	0.63	[2.28, 3.01]
Self-Compared Weekly Break Duration						
Baseline	3.08	0.60	[2.77, 3.39]	2.93	0.47	[2.67, 3.20]
Intervention	3.71	0.59	[3.40, 4.01]	2.71	0.91	[2.19, 3.24]
Follow-up	3.29	0.59	[2.99, 3.60]	2.93	0.47	[2.66, 3.20]
Average Weekday Sitting Time (hours/day)						
Baseline [†] ‡	8.39	2.97	[6.81, 9.97]	7.42	1.79	[6.28, 8.56]
Intervention [†] ‡	7.83	2.54	[6.42, 9.24]	8.46	2.44	[6.91, 10.01]
Follow-up [†] ‡	7.25	2.30	[5.97, 8.53]	8.17	2.68	[6.46, 9.87]

Table 3 Means, standard deviations, and 95% confidence intervals for self-compared and average weekday self-reported sedentary behaviors throughout the study.

Note: Bold text indicates significant differences between groups at baseline ($p < 0.05$).

[†] = Treatment group (n = 16), [‡] = Treatment group (n = 15), [§] = Treatment group (n = 12).

TIME	TREATMENT (n = 17)			CONTROL (n = 14)		
	MEAN	SD	95% CI	MEAN	SD	95% CI
Positive Affect						
Baseline	31.29	6.33	[28.04, 34.55]	30.86	7.48	[26.54, 35.18]
Intervention	32.47	6.25	[29.26, 35.68]	27.93	8.48	[23.03, 32.83]
Follow-up	32.06	7.08	[28.42, 35.70]	30.86	8.151	[26.15, 35.56]
Negative Affect						
Baseline	20.76	8.36	[16.47, 25.06]	23.00	7.17	[18.86, 27.14]
Intervention	19.76	5.99	[16.69, 22.84]	20.79	6.85	[16.83, 24.74]
Follow-up	18.29	8.53	[13.91, 22.68]	19.79	7.08	[15.70, 23.88]
Life Satisfaction						
Baseline	23.88	6.78	[20.40, 27.37]	22.36	6.88	[18.39, 26.33]
Intervention	24.76	6.95	[21.19, 28.34]	21.21	7.45	[16.91, 25.52]
Follow-up	24.59	7.91	[20.52, 28.66]	21.36	7.21	[17.20, 25.52]
Subjective Vitality						
Baseline	26.18	7.70	[22.22, 30.14]	24.14	5.46	[20.99, 27.30]
Intervention	27.24	6.24	[24.03, 30.44]	22.93	8.67	[17.92, 27.93]
Follow-up	27.71	6.76	[24.23, 31.18]	25.50	6.81	[21.57, 29.43]
Overall Subjective Well-Being						
Baseline	48.47	8.02	[44.34, 52.60]	48.00	8.49	[43.10, 52.90]
Intervention	50.76	7.60	[46.86, 54.67]	44.29	13.46	[36.51, 52.06]
Follow-up	50.82	7.73	[46.85, 54.80]	47.21	10.45	[41.18, 53.25]

Table 4 Means, standard deviations, and 95% confidence intervals for outcomes of subjective well-being throughout the study.

Note: Bold text indicates significant differences between groups at baseline ($p < 0.05$).

		<i>F</i>	<i>HYP. DF</i>	<i>ERR. DF</i>	<i>P</i>	Λ	η_p^2	$1 - \beta$
Device-Measured Sedentary Behavior								
Average daily steps	Interaction	0.015	1	28	0.902	0.99	0.001	0.052
	Main effect	0.012	1	28	0.913	1.00	0.000	0.051
Average daily standing time	Interaction	2.686	2	28	0.086	0.84	0.161	0.489
	Main effect	2.323	2	28	0.142	0.86	0.142	0.431
Average daily stepping time	Interaction	0.250	2	28	0.780	0.99	0.006	0.085
	Main effect	6.747	2	28	0.004	0.99	0.001	0.886
Average daily sitting time	Interaction	0.630	2	28	0.540	0.95	0.043	0.145
	Main effect	0.699	2	28	0.506	0.96	0.048	0.156
Average daily sit-to-stand transitions per waking hour	Interaction	0.067	2	28	0.936	1.00	0.005	0.059
	Main effect	1.166	2	28	0.326	0.92	0.077	0.235
Self-Compared Sedentary Behavior								
Self-compared weekly sitting	Interaction	2.286	2	28	0.120	0.86	0.140	0.425
	Main effect	0.490	2	28	0.618	0.97	0.034	0.122
Self-compared weekly break frequency	Interaction	2.780	2	28	0.079	0.83	0.166	0.503
	Main effect	3.783	2	28	0.035	0.79	0.213	0.641
Self-compared weekly break duration	Interaction	3.131	2	28	0.059	0.82	0.183	0.555
	Main effect	1.067	2	28	0.358	0.93	0.071	0.218
Average Weekday Sitting Time								
Average Weekday Sitting Time	Interaction	1.725	2	24	0.199	0.87	0.126	0.326
	Main effect	0.504	2	28	0.610	0.96	0.040	0.123
Outcomes of Subjective Well-Being								
Positive affect	Interaction	1.524	2	28	0.235	0.90	0.098	0.296
	Main effect	0.679	2	28	0.515	0.95	0.046	0.153
Negative affect	Interaction	0.109	2	28	0.897	0.99	0.008	0.065
	Main effect	3.887	2	28	0.032	0.78	0.217	0.654
Life satisfaction	Interaction	2.293	2	28	0.120	0.86	0.141	0.426
	Main effect	0.049	2	28	0.952	1.00	0.003	0.057
Subjective vitality	Interaction	1.205	2	28	0.315	0.92	0.079	0.241
	Main effect	3.068	2	28	0.062	0.82	0.180	0.546
Overall subjective well-being	Interaction	3.209	2	28	0.064	0.82	0.178	0.540
	Main effect	0.927	2	28	0.408	0.94	0.062	0.194

Table 5 Repeated-measures interaction effects and main effects of time for device-measured, self-compared, and average weekday sedentary behavior outcomes and outcomes of subjective well-being.

Note: Bold text indicates a significant effect ($p < 0.05$). Average daily standing, sitting, and stepping time calculated as a percentage of waking time.

Λ = Wilks' Lambda, η_p^2 = partial eta squared, $1 - \beta$ = observed power.

tailoring said prompts to the participant's action plan act as an additional cue to facilitate the intended behavior change. Previous work utilizing SMS-delivered prompts and cues has shown success in reducing SB among university students (Cotten & Prapavessis, 2016) and office workers (Rollo & Prapavessis, 2020).

The acute nature of the intervention may also have been a limitation, in contrast to SB-inducing studies that have demonstrated that 4 days (Duvivier et al., 2017) to 2 weeks (Endrighi et al., 2016) is sufficient time to significantly increase SB. As previously stated, the behavioural processes and motivations involved in

	1	2	3	4	5	6	7	8	9	10
1. Change in average daily steps		.482	.931	-.698	-.061	-.056	.109	-.059	.082	.025
2. Change in average daily standing time	.512		.599	-.894	.470	.237	-.141	.013	.319	.360
3. Change in average daily stepping time	.929	.624		-.791	.155	-.005	.049	.012	.145	.127
4. Change in average daily sitting time	-.720	-.864	-.802		-.332	-.237	.103	.000	-.309	-.309
5. Change in average daily sit-to-stand transitions per hour	.092	.396	.301	-.344		.247	-.075	.075	.182	.122
6. Change in positive affect	.028	.292	.023	-.281	.106		-.346 [†]	.390	.557	.561
7. Change in negative affect	.237	-.108	.197	.004	.127	-.455		-.315	-.330	-.384
8. Change in life satisfaction	-.097	.031	-.022	-.065	.086	.406	-.483		.613	.701
9. Change in subjective vitality	.095	.354	.131	-.325	.180	.586	-.494	.629		.792
10. Change in overall subjective well-being	.000	.328	.111	-.310	.153	.597	-.549	.701	.790	

Table 6 Pearson correlation matrix between residuals and absolute differences of device-measured SB outcomes and outcomes of SWB. ($n = 31$).

Note: Correlations between residuals are presented below the line; correlations between absolute differences are presented above the line. Average daily standing, sitting, and stepping time calculated as a percentage of waking time.

Bold text indicates a significant correlation ($p < 0.05$); bold, italicized text indicates a significant correlation ($p < 0.01$).

	1	2	3	4 [†]	5	6	7	8	9
1. Self-compared weekly sitting		-.440	-.473	.393	-.286	.017	-.298	-.238	-.319
2. Self-compared weekly break frequency	-.251		.600	-.428	.277	-.089	.323	.144	.206
3. Self-compared weekly break duration	-.326	.768		-.349	.450	-.125	.486	.402	.392
4. Average weekday sitting [†]	.317	-.263	-.061		-.236	-.008	-.531	-.376	-.320
5. Positive affect	-.036	.307	.353	-.203		-.346	.390	.557	.561
6. Negative affect	-.050	-.298	-.194	.110	-.455		-.315	-.330	-.384
7. Life satisfaction	-.297	.360	.419	-.475	.406	-.483		.613	.701
8. Subjective vitality	-.164	.279	.331	-.312	.586	-.494	.629		.792
9. Overall subjective well-being	-.330	.360	.328	-.377	.597	-.549	.701	.790	

Table 7 Pearson correlation matrix between residuals and absolute differences of self-compared and average weekday SB and outcomes of SWB. ($n = 31$).

Note: Correlations between residuals are presented below the line; correlations between absolute differences are presented above the line.

Bold text indicates a significant correlation ($p < 0.05$); bold, italicized text indicates a significant correlation ($p < 0.01$).

[†] = ($n = 27$).

performing an automatic behaviour, like SB, likely differ from those reflective and cognitive processes associated with reducing SB (i.e., alternative behaviour). Previous work utilizing this intervention in a university student population did not observe differences in SB outcomes between groups until after the third week of intervention, following the follow-up behavioral session (Sui & Prapavessis, 2018). Thus, longer intervention periods may be necessary to observe changes in habitual changes in SB. In addition, follow-up behavioral sessions (e.g., the week proceeding the first behavioral session) can promote the use of feedback, review of previous behavior, intention

formation as behavioral strategies. Together, increased contact and follow-up may improve the effectiveness of the current intervention through facilitating behavioural initiation (Rothman et al., 2011). Finally, measures used to assess SB may not be sensitive enough to capture changes in SWB. Previous work suggests that daily changes in SB impact SB outcomes (Maher et al., 2014; Maher & Conroy, 2017). Hence, adapting present instruments into previous-day recall questionnaires can provide a more accurate depiction of SB (Matthew et al., 2013) and help to capture relationships between daily changes in SB and outcomes of SWB.

INTERVENTION EFFECTIVENESS – IMPROVING SUBJECTIVE WELL-BEING

Four out of five SWB outcomes (i.e., positive affect, life satisfaction, subjective vitality, overall SWB) demonstrated small-to-medium-sized interaction effects (i.e., $0.079 \leq \eta_p^2 \leq 0.178$) favoring the treatment group, which indicates promise for the intervention in improving these SWB outcomes; however, as a whole, the intervention was ineffective in modifying this outcome. The lack of change observed among positive and negative affect may be explained, in part, by their measurement. Specifically, changes in state affect elicited by changes in SB may not be captured through weekly recall; rather, daily recall measurements may be necessary to capture these relationships (Maher et al., 2014; Maher & Conroy, 2017). Conversely, changes in more global measures of SWB, such as life satisfaction and overall SWB, may be appropriately captured through weekly recall. Overall, the ineffectiveness of the current intervention to modify SB limits the interpretation of SB and SWB relationships. However, consistent moderate strength correlations between self-reported SBs and SWB outcomes support the previous work of Maher and colleagues (Maher et al., 2014; Maher & Conroy, 2017) and Okely et al., (2019), in that changes in perceived SB may be more influential for improving SWB outcomes than objective changes in SB. Future intervention research should explore which SB outcomes elicit the greatest improvements in SWB.

LIMITATIONS

Although sample size calculations are not typically part of pilot studies, the low observed power statistics and trending p values indicate that the current work was underpowered. Drawing on previous studies that were successful in reducing SB using a similar HAPA-based intervention (Rollo & Prapavessis, 2020; Sui & Prapavessis, 2018), future iterations of the present work should aim for a sample size of 50–60 participants (i.e., 25–30 participants per group) through longer recruitment periods or recruitment over multiple semesters, in addition to the inclusion of the previously outlined strategies. Blinding of participants may also have presented as a limitation. Efforts were made to blind group allocation from participants (i.e., advertising the study as a “behaviour change study”) and anecdotally, the majority of participants mentioned they were unaware of the purpose of the study. However, some participants may have perceived the purpose of the study, which in turn may have influenced their device-measured SB and self-reported outcomes. Further, the lack of allocation blinding to the researcher presents as another limitation. Although efforts were made by the researcher to allocate randomly, the lack of concealment may have affected the delivery of the study. Utilizing third-party sequence blinding and sealed envelopes can ensure sequence and allocation concealment.

GENERALIZABILITY

Given the pilot nature of the present trial, the generalizability of these findings is limited. This trial needs replication with larger and more heterogeneous samples before definitive conclusions are drawn.

INTERPRETATION

Overall, the present randomized pilot trial provides evidence that the current acute behavioral intervention was ineffective in reducing device-measured and self-reported SB in a sample of university students over a 1-week period. Compared to previous work, this ineffectiveness may be explained by behavioural differences in reducing vs. inducing SB, strong automatic processes for sustaining SB, and/or a weak intention to reduce SB among participants. This ineffectiveness may also be in part due to the pilot study being underpowered to show statistical significance for some of the variables of interest. Together, with the addition of longer intervention periods, increased contact through follow-up sessions, and prompts/cues, the current intervention may relay greater effectiveness in reducing SB in future trials.

REGISTRATION AND PROTOCOL

The following trial and associated protocol are registered at [ClinicalTrials.gov](https://clinicaltrials.gov) under [ClinicalTrials.gov](https://clinicaltrials.gov) ID: NCT03694951 and Protocol ID: 112399, respectively.

ADDITIONAL FILES

The additional files for this article can be found as follows:

- **Supplementary Material 1.** CONSORT 2010 checklist of information to include when reporting a randomised trial*. DOI: <https://doi.org/10.5334/hpb.29.s1>
- **Supplementary Material 2.** Modified SIT-Q 7d Questionnaire. DOI: <https://doi.org/10.5334/hpb.29.s2>
- **Supplementary Material 3.** Means, standard deviations, and 95% confidence intervals for self-compared, average weekday, and domain-specific self-reported sedentary behaviors throughout the study. DOI: <https://doi.org/10.5334/hpb.29.s3>
- **Supplementary Material 4.** Repeated-measures interaction effects and main effects of time for domain-specific sedentary behavior outcomes. DOI: <https://doi.org/10.5334/hpb.29.s4>
- **Supplementary Material 5.** Pearson correlations between residuals and absolute differences of domain-specific SBs and outcomes of SWB. ($n = 31$). DOI: <https://doi.org/10.5334/hpb.29.s5>

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COMPETING INTERESTS

The authors denote no other perceived or actual conflicts of interest with the trial.

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