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Effects of breaking up sitting with light-intensity physical activity on cognition and mood in university students

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Background: University students often exhibit high levels of sedentary behavior that is negatively associated with cognition and mood. On the other hand, light-intensity physical activity (LIPA) may improve cognitive performance and mood. Therefore, this study investigated the acute effect of LIPA breaks during prolonged sitting on attention, executive functioning, and mood.

Methods: A randomized crossover design was used in this study. In total, 21 healthy adults (15 women, age = 24 ± 3 years, BMI = 23 ± 2 kg/m^2) completed three prolonged sitting conditions: (1) without a demanding cognitive task (SIT), (2) with a demanding cognitive task (COGN), and (3) with every 25 min sitting interrupted by a 5-minute walk (INTERRUPT). Attention, executive function (response inhibition, task shifting, and working memory updating), and mood were assessed before and after each condition.

Results: Linear mixed models analyses showed that prolonged sitting frequently interrupted by LIPA (INTERRUPT) or with cognitively demanding activities (COGN) significantly improved task shifting compared to SIT. However, INTERRUPT did not significantly improve task shifting compared with COGN. No significant acute effects on attention, response inhibition, working memory updating, or mood were found.

Conclusions: Frequent LIPA breaks or cognitively demanding activities have a selective, acute positive impact on one aspect of cognitive performance compared to idle sitting. No evidence was found that LIPA breaks have an acute improvement in attention, executive function, and mood compared to sitting with cognitive loading. To further investigate the effect of PA on cognitive performance, it is necessary to consider cognitive loading and control for the cognitive activity during sitting in the experimental design.

KEYWORDS
attention, executive function, light-intensity physical activity, sedentary behavior, young adults

1 | INTRODUCTION

Higher education commonly concurs with prolonged sitting. University students sit 9.8 h per day on average,[1] suggesting that they have a sedentary lifestyle. Furthermore, many university students do not achieve 150–300 min of moderate-intensity or 75–150 min of vigorous-intensity physical activity per week, as recommended by the World Health Organization (WHO).[2] Considering the well-established evidence for the detrimental effects of sedentary behavior on physical health, it is of pertinent importance to improve the situation for university students. The same line of reasoning may hold for their brain health.

Brain health, which involves both cognitive performance and mental health, strongly determines the learning and academic success of young adults. Several studies have shown that moderate to vigorous physical activity (MVPA) has a positive impact on cognitive performance[3,4] and mental health,[5] while research into the relationship between light-intensity physical activity (LIPA) and cognitive performance or mental health is very limited and results are mixed. On the other hand, several reviews show adverse associations of sedentary behavior with cognitive performance[6] and mental health.[7,8] When targeting the young adult population only, another systematic review concluded that the relationship between sedentary behavior and cognitive performance is still unclear.[9] Studies on the association between sedentary behavior and mental health among college students are equivocal as well. Lee and Kim found symptoms such as anxiety, depression, and stress to be significantly increased with sitting time.[10] In contrast, other studies have not identified a significant association between sedentary behavior and anxiety[11,12] or depression.[11] In conclusion, more studies are needed to establish whether LIPA and sedentary behavior have an impact on cognitive performance and mental health.

The WHO's latest guidelines recommend reducing sedentary behavior and replacing sitting time with LIPA to maintain physical health.[13] Indeed, several recent studies have shown that reducing sitting time with only LIPA is effective and superior to exercise in improving metabolic health,[14,15] including glucose metabolism.[16,17] Wheeler et al. suggested replacing sedentary behavior with intermittent LIPA may protect against cognitive decline by reducing glycemic variability. Since glucose metabolism plays an important role in brain health, we expect that replacing sitting with LIPA breaks will be effective to maintain or improve cognitive performance. So far, only a few experimental studies explored the impact of frequent breaks in prolonged sitting on cognitive performance. These studies reported positive effects on cognitive performance[8,18] or no improvements in cognitive performance.[19,20] A prospective analysis indicated substituting prolonged sitting with LIPA for 1 year to be associated with improved mood among 20- to 35-year-old healthy adults.[21] The present study aims to investigate the acute impact of frequently interrupting prolonged sitting time with light-intensity physical activity on cognitive performance and mood during sitting. For that purpose, we compared cognitive performance and mood after prolonged sitting and after prolonged sitting that was frequently interrupted by LIPA. In this study, we focus on the cognitive domains of attention[22] and executive functioning,[22,23] with response inhibition, task shifting, and working memory updating as key components.[24]

While the primary focus of the current study is on sitting interrupted by LIPA, we recognize that cognitive activity during sitting may affect cognitive performance as well. Research suggests that older adults who sustainably engage in learning new and demanding cognitive skills for 3 months maintained their cognitive functioning.[25] This finding is consistent with the idea that cognitive engagement interventions can promote the maintenance of brain activity and cognitive function in later life.[26,27] Note, however, that this idea is based on studies with long-term interventions. Similar research with young adults is scarce. It remains to be seen whether studying or engaging in mentally challenging tasks has acute effects on young adults. If cognitive activity has an enhancing effect on cognitive capacity and performance in younger adults, it is essential to control cognitive activity. To this end, we added a second control condition: sitting with a demanding cognitive task. This enabled us to see which effect a cognitively demanding task has on subsequent cognitive performance and mood compared with the idle sitting. Moreover, it enabled us to investigate whether the effect of LIPA on cognitive performance and mood goes beyond the effect of cognitive load.

2 | METHOD

2.1 | Participants

To be eligible to participate in the study, participants had to meet the following criteria: aged between 18 and 30 years, currently being a student in higher education, non-native English speaker, BMI between 18 and 25 kg/m^2, and less than 150 min moderate to vigorous physical activity per week. Both women and men were included. Exclusion criteria were any drug use (not including oral contraceptives), being diagnosed with any neuromuscular disease, or scoring between 11 and 21 in each anxiety and depression subscale on the Hospital Anxiety and Depression Scale.[28] Participants were recruited via flyers and posters among students of the Maastricht University.

This study was approved by the Ethics Review Committee of the Faculty of Health, Medicine and Life Sciences of Maastricht University (FHML–REC) and was registered as a clinical trial (NCT04716582) on ClinicalTrials.gov. All the participants provided informed consent.

2.2 | Procedure

After expressing interest in participation, candidates received an e-mail including an enrollment questionnaire. If participants passed this initial online screening, they were invited to the laboratory of the Department of Nutrition and Movement Sciences of Maastricht University for a further screening visit. During this visit, participants were first asked to fill out the informed consent. Then, their height and body mass were assessed and they were familiarized with the cognitive performance tests. Participants first performed a paper-and-pencil test (attention), then did three computerized executive function tests (response inhibition, task shifting, and working memory updating), and filled out a mood questionnaire under the guidance of a research staff member. To make sure they understood all tests, they were allowed to ask any questions.

During the 48 h before each intervention day, participants were asked to report their wake-up and sleep time themselves. In addition, they were provided with verbal and written instructions: no alcohol, not more than three caffeinated drinks per day, at least 6 h of sleep, and no MVPA.

2.3 | Study protocol

Participants attended three separate condition visits with 6–14-day washout periods in between. The three conditions, cognitively unloaded, uninterrupted sitting (SIT), uninterrupted sitting with a cognitive task (COGN), and cognitively unloaded sitting interrupted by light physical activity (INTERRUPT), were completed in a counterbalanced, randomized order (Figure 1). On a test day, participants arrived in the laboratory or meeting room in the

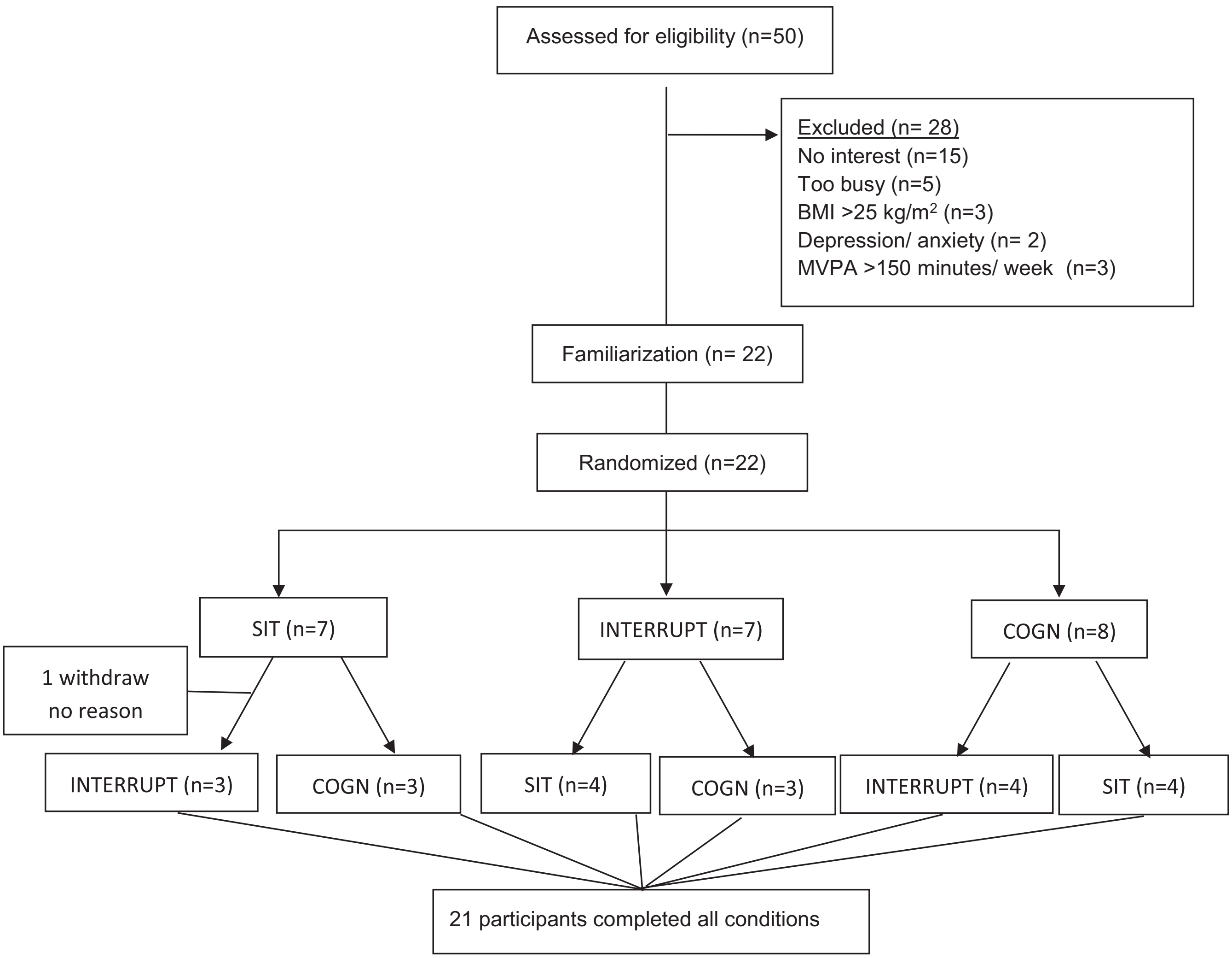

FIGURE 1 Standardized recruitment and reporting trials flow diagram

morning and sat down for 20 min to achieve a steady state. They were offered a standardized breakfast (2/3 slices of bread with jam or peanut butter provided). After eating, they were asked to fill out the mood questionnaire and to perform four cognitive performance tests in the same sequence as familiarization. Intervention/control conditions started after they finished the cognitive performance tests. During the intervention/control condition, they were offered a snack (one slice of bread with jam or peanut butter). Attention, executive functioning (response inhibition, task shifting, and working memory updating), and mood were measured again immediately after 4-hour sitting.

2.3.1 | Experimental conditions

In the SIT condition, participants remained seated for 4 h. During sitting, they were asked to watch a series of neutral, informative documentaries. Participants were only allowed to rise from their chairs to visit the toilet (4 m for females, 20 m for males; both on the same floor).

In the COGN condition, participants remained seated for 4 h and were only allowed to rise from their chairs to visit the toilet. During the 4 h of prolonged sitting, participants received the online General Educational Development (GED) task as a demanding cognitive task, instead of watching documentaries. The GED task involved four subjects: mathematics, language arts, science, and social studies. Instead of watching documentaries, participants performed the task and answered all the questions in 4 h.

In the INTERRUPT condition, participants sat for 4 h, with a 5-minute light-intensity physical activity break after every 25 min of sitting. Thus, during the 4-hour period participants were active for 40 min in total. The 5 min of light-intensity physical activity consisted of a walk along a predefined route through the department's corridors and areas of Maastricht University Hospital. The walking speed was set at 3.6 km/h. Participants were accompanied by research staff during the walks. When the participants sat, they watched a series of documentaries, which were similar to those provided during the SIT condition.

2.3.2 | Diet

Although not strictly controlled, participants were instructed to maintain their usual dietary habits, during the 48 h before the experimental days. However, participants were provided a standardized meal including breakfast and snacks during each test day. No beverages, other than 500 ml of water, were allowed.

2.4 | Assessment of attention and executive function

To assess attention and executive functioning, the paper-and-pencil version of the D2 Attention Test (Hogrefe) and computerized versions of the Stroop, the Trail Making Test (TMT), and the 2-Back Test (Inquisit package from Millisecond Software) was used. Each test was performed twice during a test day, before the intervention, and immediately after the intervention. Cognitive tests were administered in a fixed order: (1) D2 Attention Test, (2) Stroop Test, (3) TMT, and (4) 2-Back Test.

2.4.1 | Attention: D2 Attention Test

To measure selective attention, a paper-and-pencil version of the D2 Attention Test[29] was applied. The test consisted of 14 lines with 47 randomly mixed letters 'p' and 'd' per line, 658 items in total. Each item was a letter 'p' or 'd' accompanied by 1, 2, 3, or 4 small dashes. Participants were required to identify and solely cross out all 'd' with two dashes at a rate of 15 s per row. The standardized time per line was 20 s. In this study, we decided to shorten it to 15 s per line to prevent a ceiling effect as our participants were all university students and thus expected to function on a rather high level. The time to complete each of the 14 lines was predefined as 3.5 min. Dependent variables for attention were concentration performance (D2 CP), and overall success (D2 TN-E). Here, D2 CP was the number of correctly crossed out 'd's minus the number of commission errors (when irrelevant items were crossed out), and the D2 TN-E was the total number of items processed minus errors of omission (when relevant items were not crossed out) and errors of commission. Regarding attention, D2 TN-E reflected attentional and inhibitory control. D2 CP showed the coordination of performance speed and accuracy.

2.4.2 | Response inhibition: Stroop Test

To test response inhibition, a modified computerized version of the Stroop Test was used.[30] The test consisted of congruent trials, in which the color word and the color it was presented in were the same, and incongruent trials, in which the color word and the presentation color were different. Colored rectangles were presented as control trials. Participants were given color words written in color and were asked to choose the print color of the word (or rectangle) instead of its meaning by keyboard responding as fast as possible. Participants completed 84 randomly intermixed trials (congruent, incongruent, and control trials) in one test block. For each trial reaction time (RT) and correctness of the response were recorded. For each condition (congruent, incongruent, and control) the mean reaction time (mRT) and the accuracy were assessed. Stroop mRT interference and Stroop Accuracy interference were dependent variables for inhibition. They were calculated as the differences between mRT and accuracy respectively between incongruent and congruent trials.

2.4.3 | Shifting: Trail-Making Test

To assess task shifting, the TMT was taken.[31] Participants were asked to draw a line using the computer mouse from dot to dot in a specific sequence. In TMT part A the dots were numbered (1–25) and the numbers directed the line drawing. In TMT part B dots were marked with both numbers (1–13) and alphabetic letters (A–L). While drawing the line, the participants had to switch numbers and letters continuously. (i.e., 1-A-2-B-3-C etc.). The time required to draw each of the lines was recorded. TMT reaction time (RT) interference was calculated as the difference in completion time between TMT parts A and B (i.e., B minus A) and considered as the outcome measure for shifting.

2.4.4 | Updating: 2-Back Test

Updating capacity was assessed using the N-Back Test, which is a go/no-go working memory performance task with increasing levels of difficulty.[32] In the current study, we used a 2-Back Test, which included six target trials and 14 non-target trials, 20 trials in total. Participants were asked to press the keyboard 'A' if the shape was the same as the one presented two trials before and no response if the shape was different. The correctness of the responses (score = hits number − false alarms number) was measured.

2.5 | Assessment of mood state

To evaluate mood state, an abbreviated version of Profile of Mood States (POMSs)[33] was used twice during each experimental day, immediately before and after the 4-hour intervention, respectively. The questionnaire contained 40 items. Dependent variables were Tension (TEN), Anger (ANG), Fatigue (FAT), Depression (DEP), Esteem-related Affect (ERA), Vigor (VIG) and Confusion (CON), and Total Mood Disturbance (TMD). The total mood score was calculated by summing the total score of negative subscales minus the totals for the positive subscales: TMD = (TEN + ANG + FAT + DEP + CON) − (ERA + VIG).

2.6 | Statistics analysis and calculations

Sample size calculations were performed in G*Power. We estimated the effect size at 0.3 for light-intensity walking breaks on cognitive performance based on a comparable study by Mullane et al.[18] A sample of 18 participants was required to detect such an effect with a power of 0.80 and a two-tailed alpha of 0.05 based on a repeated-measures analysis of variance (ANOVA). Considering a 10% drop-out rate, we aimed at the recruitment of 21 participants. Statistical analyses were performed using IBM SPSS Statistics for Windows version 25.0 (IBM Corp.). Categorical variables are presented as percentages, where means (SD) are reported for numerical variables. Linear mixed model (LMM) analyses were used to assess the effects of experimental conditions on cognitive performance and mood state outcome variables, where a random intercept was included to account for the nesting of repeated measurements within a participant. Test day (first, second, third), condition (SIT, COGN, and INTERRUPT), time (pre and post), and interaction between time and condition were included as fixed factors, where the interaction assessed the condition effect corrected for the baseline value of the same test day. To take into account a possible effect of the test day, a three-way interaction between test day, condition, and time was included as well (together with the two-way interaction terms test day × condition, test day × time). In case this provided a significant three-way interaction effect, the condition effect corrected for the baseline value of the same test day was reported for each test day separately. If the three-way interaction was not significant, it was removed from the model and the corrected condition effect was presented for all test days combined. The standardized effect size ("Cohen's d") was calculated as the estimated mean difference divided by the square root of residuals in the linear mixed model. When Cohen's $d = 0.2$, it was interpreted as a small effect size. When Cohen's $d = 0.5$ and 0.8, they were considered as medium and large effect sizes, respectively. In our case, Bonferroni correction for p-values was applied if LMM reported a significant overall interaction effect by condition × time among 3 conditions.

3 | RESULTS

In total, 21 participants, 15 women and six men with a mean age of 24 years (SD = 3 years) and mean BMI of

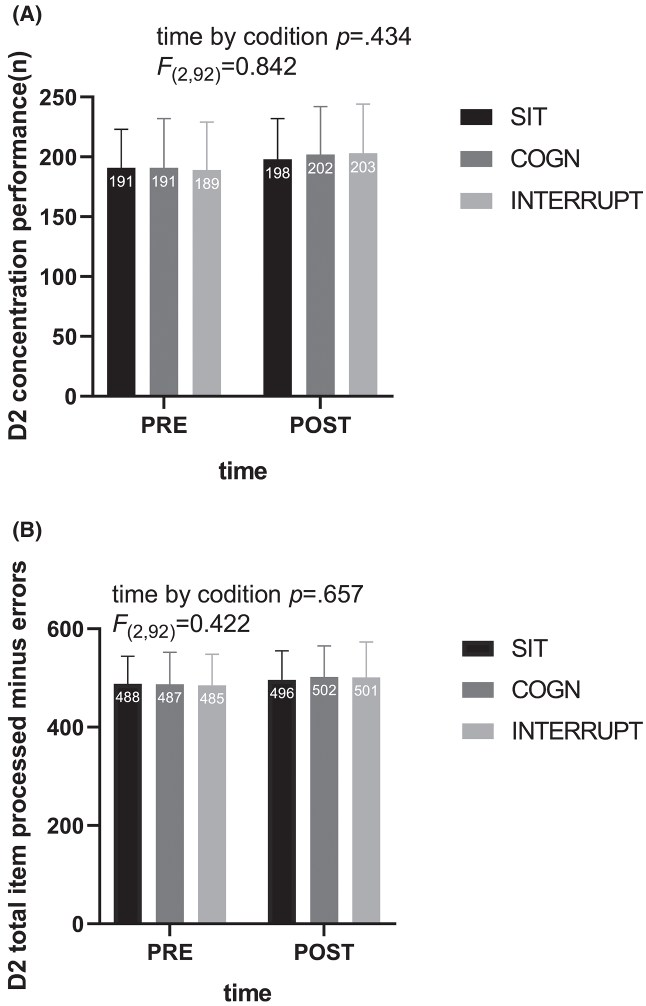

FIGURE 2 Observed mean (SD) D2 attention scores per condition and time

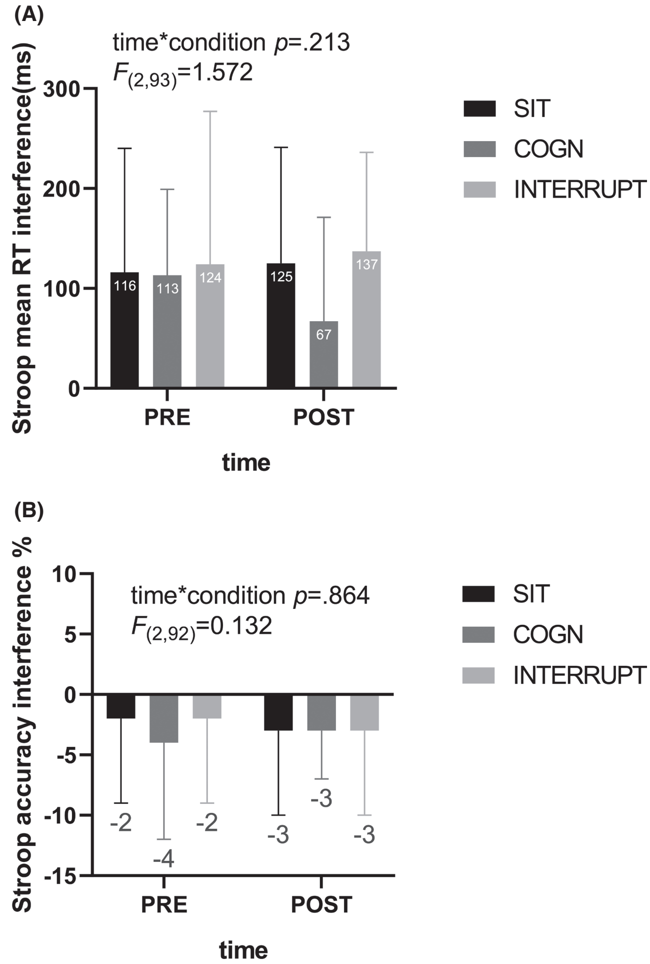

FIGURE 3 Observed mean (SD) Stroop Test scores per condition and time

23 (SD = 2 kg/m^2) underwent all conditions. For the 2-Back Test, 5 extreme values were considered impossible and were therefore excluded and considered as missing data in the analysis. Only for the Stroop RT interference, a significant three-way interaction of test day, condition, and time was found. For the other variables, no significant influence of test day was found, which indicated that there was probably no carry-over effect. In addition, there were only seven participants per condition per test day. Therefore, we decided to report the effects for the three test days combined instead of for each test day separately.

3.1 | Cognitive performance

For the D2 Attention Test, there was no significant overall interaction effect between condition and time in D2 CP ($F_{(2, 92)}$ =0.842, p = 0.434; Figure 2A), D2 TN-E ($F_{(2, 92)}$ =0.422, p = 0.657; Figure 2B), suggesting that the mean difference in D2 Attention Test performance between the pre- and post-measurement did not vary significantly across SIT, INTERRUPT, and COGN conditions.

For the Stroop Test, no significant interaction effects by condition and time in interference score for response time ($F_{(2, 93)}$ =1.572, p = 0.213; Figure 3A) or accuracy ($F_{(2, 93)}$ =0.146, p = 0.864; Figure 3B) were observed. This meant that the mean differences between pre- and post-measurement for inhibition were similar for the three conditions.

For the TMT, there was a significant interaction effect between condition and time in response time interference score ($F_{(2, 91)}$ =3.442, p = 0.036; Figure 4A), indicating that there are significantly different effects of the three conditions on task shifting. After pairwise comparisons, INTERRUPT and COGN significantly showed on average a lower reaction time interference score (faster RT) than SIT (Cohen's d = 0.94, 1.04, respectively; Figure 4B) In other words, comparing idle sitting, interrupting sitting by LIPA, and sitting with

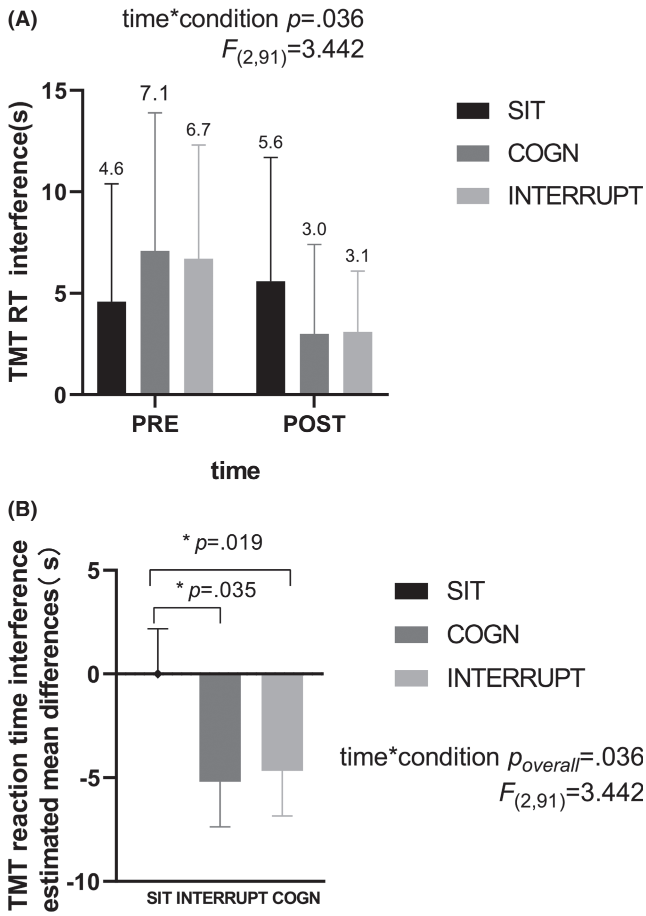

FIGURE 4 Observed mean (SD) Trail Making Test scores per condition and time

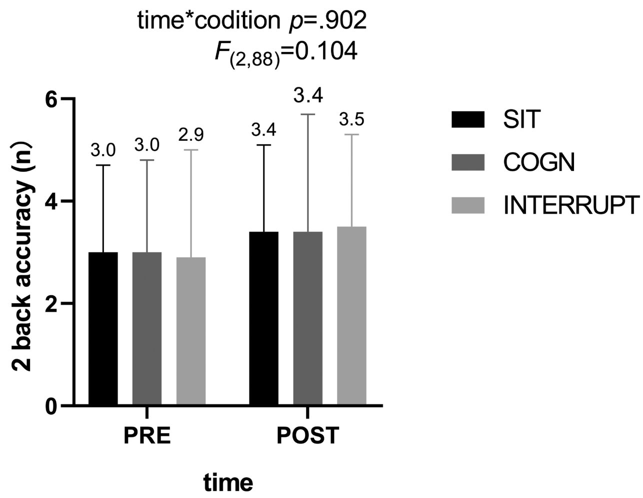

FIGURE 5 Observed mean (SD) 2-Back Test scores per condition and time

cognitive demanding both showed better performance in the TMT.

For the 2-Back Test, no significant interaction effect ($F_{(2, 88)}$ =0.104, p = 0.902; Figure 5) was found in accuracy. The difference between pre- and post-measurement for updating was not significantly different between the three conditions.

3.2 | Mood states

As shown in Table 1, no significant interaction effects between condition and time were observed in tense ($F_{(2,92)}$ = 1.020, p = 0.365), ANG ($F_{(2,93)}$ = 0.991, p = 0.375), FAT ($F_{(2, 93)}$ = 2.214, p = 0.115), DEP ($F_{(2, 92)}$ = 1.926, p = 0.152) and CON ($F_{(2, 91)}$ = 2.535, p = 0.085). No significant interaction effects between condition and time were observed in esteem-related affect ($F_{(2, 92)}$ = 0.212, p = 0.810), vigor ($F_{(2, 91)}$ = 0.507, p = 0.604), and TMD ($F_{(2,90)}$ = 1.995, p = 0.142). This suggested no significant differences in all mood outcomes among SIT, INTERRUPT, and COGN conditions.

4 | DISCUSSION

This study compared the effects of sitting interrupted by short bouts of LIPA with uninterrupted sitting on cognitive performance and mood. The secondary aim was to compare two control conditions, idle sitting, and sitting while being engaged in a challenging cognitive task. Task shifting, one of the three executive functions measured, significantly improved after both prolonged sittings interrupted by light-intensity physical activity (INTERRUPT) and sitting with cognitive demands (COGNs), compared with the idle sitting. However, task shifting did not differ significantly between the INTERRUPT and COGN conditions. The other two executive functions (i.e., inhibition and working memory updating), as well as attention and mood, were not significantly different between the three conditions.

It is a novel and interesting finding that sitting with cognitive demands (COGN) positively and acutely affected task shifting to a similar extent as breaking up sitting with LIPA (INTERRUPT) as compared to idle sitting. This implies that when comparing physical activity interventions to a seated condition, it is important to precisely control cognitive activities during sitting. To be more specific, whether a sitting control condition involves either or not a cognitively challenging task will affect the comparison with a physical activity intervention. Some previous studies that had a similar design as the current study differed in the instructions that were given to the participants in the control condition. For example, Bergouignan et al.[19] asked participants to read, use a computer, and watch TV during 6-hour sitting. Mullane et al.[18] let participants remain seated while performing computer-related tasks, like in a typical office environment. However, the authors

TABLE 1 Observed score for the mood questionnaire across conditions and time

Mood	Time	Condition SIT Mean (SD)	COGN Mean (SD)	INTERRUPT Mean (SD)	*p*-Value for time * condition
TEN	POST	2.4 (1.7)	2.3 (1.7)	1.9 (2.1)	0.365
	PRE	1.5 (1.3)	2.3 (2.2)	1.9 (2.0)	
ANG	POST	1.0 (1.3)	1.1 (2.5)	0.4 (1.0)	0.375
	PRE	0.4 (0.6)	0.4 (1.0)	0.4 (0.8)	
FAT	POST	5.6 (3.7)	6.0 (4.2)	3.5 (2.7)	0.115
	PRE	2.5 (3.1)	3.2 (4.1)	2.3 (3.8)	
DEP	POST	1.0 (1.5)	0.9 (1.4)	0.6 (1.3)	0.152
	PRE	0.5 (0.9)	0.7 (1.2)	1.2 (2.3)	
CON	POST	2.8 (1.8)	2.0 (1.7)	1.7 (1.5)	0.085
	PRE	2.0 (1.5)	2.4 (2.2)	2.1 (2.0)	
ERA	POST	12.3 (3.9)	11.6 (3.5)	12.5 (3.8)	0.810
	PRE	13.7 (3.7)	12.5 (3.8)	13.9 (3.7)	
VIG	POST	3.6 (3.8)	3.7 (3.5)	5.1 (4.1)	0.604
	PRE	6.8 (3.8)	5.8 (4.7)	7.3 (4.2)	
TMD	POST	−3.0 (11.5)	−3.1 (10.8)	−9.5 (11.6)	0.142
	PRE	−13.6 (8.6)	−9.3 (11.0)	−12.7 (11.6)	

Abbreviations: ANG, anger; CON, confusion; DEP, depression; ERA, esteem-related affect; FAT, fatigue; TEN, tension; TMD, total mood disturbance; VIG, vigor.

did not consider these cognitive demands, which may have been distinct from leisure time activities or activities with higher cognitive demands. None of these two studies found an improvement in task shifting by LIPA. This may be explained by the sitting conditions, which were not controlled for cognitive activity. Thus, it is necessary to carefully take cognitive activity during sitting into consideration when designing these experiments.

In our study, we found that 40-min LIPA breaks improved task shifting, but seemed not sufficient enough to elicit an acute positive effect on other aspects of executive functioning. Due to the mixed results in existing studies, which may result from uncontrolled cognitive load in the sitting control condition, our results are not entirely comparable to the existing literature. With regard to the acute effect on cognitive performance, the intensity level of physical activity has been suggested to play an important role. A meta-analysis and systematic review showed that acute MVPA had an immediate positive effect on cognitive performance.[34] It suggests that at an acute level, the greater the training intensity, the stronger the effect on cognitive performance. In the present study, the intensity level was comparatively low, which might be the reason why not all aspects of executive functioning were improved. When it comes to the chronic effects of LIPA, a recent study evaluated 28 weeks of sit-stand desk use in school and reported improvements in executive functioning.[35] This may denote that LIPA boosts cognitive performance in the long run.

The absence of effects of LIPA on mood in the current study is not consistent with the results from a similar study by Bergouignan et al.[19] In this study, participants engaged in 5-min bouts of treadmill walking every hour to interrupt 6 h of sitting. They found that this intervention significantly increased vigor, decreased fatigue, and improved total mood level compared to an uninterrupted sitting condition when using the same mood questionnaire as in the present study (POMS). Possibly, 4 h of sitting is not long enough for university students to accumulate fatigue and change mood, irrespective of them being engaged in leisure activities or cognitive tasks. Other research focused on active desk workstations in office environments and showed improvements in mood or energy level as compared to an idle sitting condition. In Pilcher and Baker's research, light physical activity (45 min of slow biking at a FitDesk) improved motivation and morale compared to sitting at a traditional desk. The mood was tested during the intervention, which was different from testing after intervention in our design.[36] Thorp and her colleagues[37] found a significant reduction in fatigue levels when participants had a transition from a seated to a standing work posture every 30 min across an 8-hour workday for 5 days. Four hours of standing per day for 5 consecutive days is a relatively strong intervention compared to an accumulated 30 min of walking during 4 h of sitting in the current study, which may explain the different effects on fatigue across these studies.

The main strength of this study was that we achieved 100% compliance from our participants under supervised laboratory conditions. A limitation of the study is that we chose healthy, non-overweight individuals without depression and anxiety, which limits the generalizability of our findings to the broader population. Another possible limitation is that our intervention of a 5-min walk every 30 min may not be feasible in real life.

In conclusion, interrupting sitting with LIPA breaks or imposing a cognitive challenge during sitting significantly improved task shifting compared to idle sitting in university students. No significant acute effects on response inhibition, working memory updating, attention, and mood were found. These results suggest that LIPA may have a selective impact on cognitive performance that does not exceed the effect of cognitively demanding activities. To further investigate the effect of LIPA, it is necessary to control for cognitive load during sitting in the experiment design.

5 | PERSPECTIVE

As far as we know, this is the first study to investigate the effect of LIPA compared to both idle sitting and sitting with cognitively demanding activities. According to our results, the effect of LIPA on task-shifting performance did not exceed the effect of cognitively demanding activities. This suggests that it matters what cognitive activities participants engage in while sitting. In other words, sitting while studying differs significantly in its baseline effect on cognitive performance from sitting while passively watching television. For experimental studies comparing physical activity with sedentary behavior in their effect on cognitive performance, we recommend controlling cognitive activity during sitting if sitting is an essential part of the control condition. For this reason, it is warranted to design more real-life conditions, for example, high-intensity studying during prolonged sitting, which is common in an academic setting.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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