Breaking sedentary behaviour among university students: Benefits of incorporating cycling desks concurrently with an academic learning task at light, but not moderate, intensity

Dupont F[1]; Oliva F[1]; Pitois L[1]; Chagnon M[2]; De Fátima Guimarães R[3]; Mathieu ME[1,4]

[1] École de kinésiologie et des sciences de l'activité physique, Université de Montréal, Montréal, Canada

[2] Département de mathématiques et de statistique, Université de Montréal, Montréal, Canada

[3] Département des sciences de l'activités physique, UQTR, Trois-Rivières, Canada

[4] Centre de recherche du CHU Sainte-Justine, Montréal, Canada

Corresponding author:
Pr. Marie-Eve Mathieu
me.mathieu@umontreal.ca

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Abstract

Breaking sedentary behaviour among university students: Benefits of incorporating cycling desks concurrently with an academic learning task at light, but not moderate, intensity

Introduction: Physical activity (PA) can enhance physical and mental health, with implications for academic performance. Method: This randomized crossover trial aimed to assess the effects of different intensities of PA using cycling desks on mental workload, anxiety and academic performance in university students (n=24). Participants underwent sedentary (SED), low-intensity (CD_{LPA}), and moderate-intensity (CD_{MPA}) cycling desk conditions during an academic task across three sessions. The task involved watching a 30-minute video followed by a written exam. We measured perceived workload and anxiety post-video and post-exam with NASA-TLX and POMS-SF, respectively, while Tobii glasses 2 were used to measure selective visual attention during the video. Result: Significant interactions between condition and time for the perceived workload ($p<0.001$; $n2=0.444$) and a time effect for anxiety ($p=0.015$; $n2=0.174$). Notably, CD_{MPA} led to a higher perceived workload during the video compared to SED and CD_{LPA}. We also observed differences in selective visual attention and exam scores between conditions ($p<0.001$ and $p=0.009$, respectively), favouring SED and CD_{LPA} over CD_{MPA}. Conclusion: Our findings suggest that CD_{LPA} use can increase PA in students and offer academic benefits, whereas CD_{MPA} results in higher mental load without anxiety benefits. Therefore, low-intensity cycling desks increase PA without disrupting learning processes.

Keywords: Sedentary behaviour, Cycling desks, cognitive load, anxiety, academic performance

Introduction

Sedentary behaviour is a problem among university students. In fact, university students experience high levels of sedentariness due to prolonged sitting in class or while studying [1,2]. It is estimated that universities students spend an average of 8 hours per day in sitting time [3,4], making the 18-35 years old adults' group with the highest daily sitting time [3,5,6]. Prolonged periods of sitting have been linked to an elevated risk of various chronic illnesses and to increase the likelihood of all-cause and cardiovascular mortality [7]. Too much sitting time also leads to increased stress, anxiety and depression in university students [8-11].

The issue of physical activity also presents challenges for students. Guidelines generally recommend that individuals engage in at least 150 minutes of moderate to vigorous physical activity per week, including muscle-strengthening exercises [12,13]. However, only 61% of Canadian and 53% of American university students adhere to these recommendations [4,14]. The first year of university is crucial since there is a notable decline in moderate and vigorous physical activity during this period [15,16]. Incorporating moderate to vigorous physical activity into a student's routine can have numerous benefits, such as improving cardiovascular health [12,13], mood, and reducing stress and anxiety [12,17]. Additionally, physical activity has been linked to improved academic performance, including better grades, higher test scores, and enhanced cognitive function [18,19].

University students face several challenges when it comes to engaging in physical activity and breaking sedentary behaviour. The most significant challenge is their busy schedules, making it difficult to find the time and energy to prioritize physical activities [20]. Moreover, a lack of motivation and social support can also make it difficult for them to engage in physical activity [20,21]. Some students may lack the intrinsic motivation necessary to exercise regularly, while others may struggle to find friends or family members interested in physical activity [22]. Limited access to facilities is another barrier that can make it challenging for university students to engage in physical activity. Some students may not have access to a gym or other facilities that offer opportunities for physical activity or have financial limitations, which can limit their options for exercise [20,21]. Overall, students spend a significant amount of time sitting in lectures, studying, or working on assignments, which can make it difficult to break the cycle of sedentary behaviour and incorporate more physical activity into their daily lives

Combining cognitive tasks with physical activity is gaining attention [18,23] and the integration of PA concurrent to cognitive work may represent a way to insert active time into the student's schedules. Active workstations such as cycling desks that generate light to moderate physical activity have become a strategy to combat sedentary behaviour in schools [24] and workplaces [25]. Cycling desks are designed to allow people to pedal while working, which is an effective way to stay active and break up sedentary time [25]. Cycling desks can enhance physiological health indicators such as cardiovascular function, blood glucose control and energy expenditure [26]. In addition, physical health benefits may enhance cognitive performance, particularly in tasks that require short-term sustained attention, working memory, and decision-making [27]. Cycling desks may also positively impact arousal levels, which is essential for individuals who must stay alert and focused throughout the day [28]. However, the literature addressing the use of cycling desks on cognitive function in an educational objective is limited. For example, most studies have assessed cognitive functions such as memorization and attention using neuropsychological tests like the n-back test and Stroop battery test [29-31]. However, these tests have limited ecological validity as they are highly artificial and abstract tasks [32]. Therefore, the findings from these studies provide limited insight into the more complex tasks that students may encounter in their daily work, such as studying. Tools such as eye-tracking could give us added information on selective visual attention, such as eye position and movement and detailed information on what users looked at and how long in complex tasks such as studying. Also, emotional factors like perceived workload and anxiety during dual-tasking, such as cycling desks, are still underexamined in the literature. Perceived workload, stress and anxiety have an impact on academic performance [33,34]. Thus, a better understanding of the impact of cycling desk use with various physical intensities on workload and anxiety is necessary to address further recommendations. Finally, most studies involving dual-tasking with physical and mental tasks have mostly focused on pediatric or geriatric populations. Thus, little is known about the effects of physical activity during cognitive tasks such as memorization and learning in post-secondary students [35].

Following the existing knowledge, this study compares the acute effects of low and moderate intensities of PA using cycling workstations and a sedentary position concurrent to a cognitive learning task in university students. We hypothesize that light and moderate intensities of physical activity will reduce mental workload and anxiety following the dual-task compared to the sedentary position. The second hypothesis is that selective visual attention will be higher in the cognitive-cycling tasks than in the sedentary position.

Method

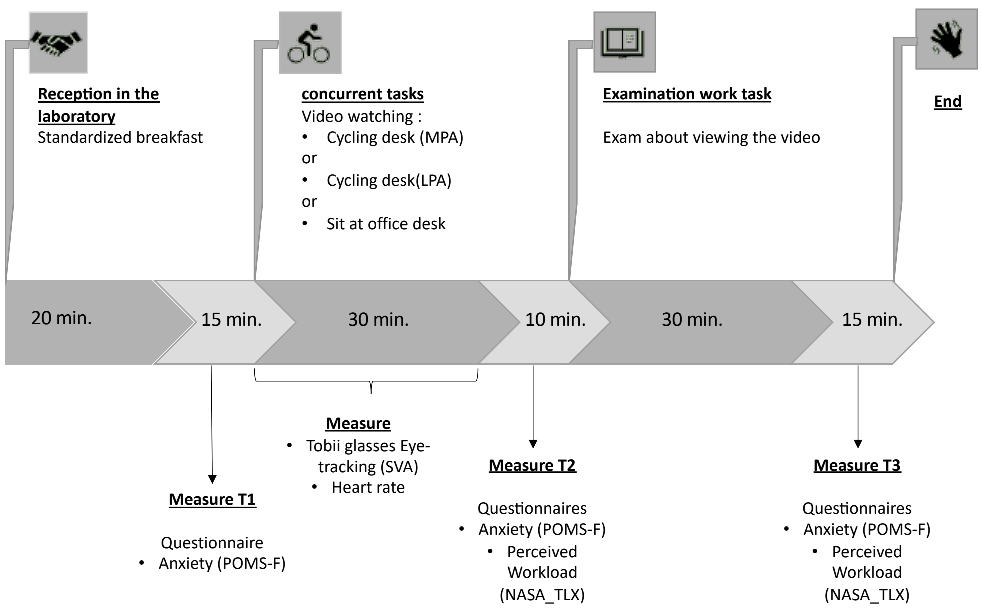
Population

Recruitment has been done among undergraduate and graduate students of the Université de Montréal. Recruitment forms were sent electronically to the student associations and posted on the university bulletin boards. The participant had to be between 18 and 65 years old to be included in the study. Participants were required to sign a consent form and fill out a health form informing us of any dietary restrictions they may have given that a second part of the study involved eating habits (not presented here). Exclusion criteria were: following any specific diet or regimen, having a known eating disorder (e.g., bulimia or anorexia), taking medications (e.g., insulin, beta-blockers or corticosteroids), having chronic gastrointestinal problems (e.g., Crohn's disease), having food intolerances or allergies, having physical limitations that would prevent you from being physically active and have photosensitive epilepsy. The project was conducted according to the ethical certificate *#CERC-21-003-P from the* Clinical Research Ethics Committee of *the Université de Montréal*.

Experimental design

A first virtual meeting was done with the participant. The meeting consists of reviewing the consent form with the participant and ensuring he respects all the inclusion criteria. Then a health and lifestyle questionnaire adapted for the IPAQ questionnaire [36] was sent to the participant to complete before the first session in the laboratory. The participants had to complete a weekly experimental session for three consecutive weeks. The three conditions [control (SED), cycling desk at light physical activity (CD_{LPA}) and cycling desk at moderate intensity (CD_{MPA})] were performed in a randomized order. Participants' intensity stages were categorized following the Canadian Society for Exercise Physiology recommendations. A typical session consisted of arriving at the lab at 09:00 am and eating a standardized breakfast. At 9:15 am, the participant was invited to watch on an iPad (8th generation, Apple, CA, USA) the first 30 minutes of a documentary (Babies 2020, season 2, episodes 8-11-12, Netflix). Following the video session, the participant answered a 30-minute online exam related to the documentary seen previously (see fig. 1).

Figure 1. Laboratory sessions



Experimental Conditions

The SED session consists of watching the 30-minute video comfortably sitting on a desk chair. In the light-intensity session (i.e., CD_{LPA}), the participant had to watch the video while pedalling at the cycling desk (ProPlus 36™, Varidesk, Texas, United States). The cycling desk was set at a resistance of 3 (i.e., 22 watts for a cadence of 60 revolutions per minute). The participant was instructed to maintain a consistent pedalling pace concurrent with the video without experiencing shortness of breath or physical exhaustion. In the moderate-intensity session (i.e., CD_{MPA}), the participants had to watch the video while cycling on a bike (Lifecycle 9500HR Upright bike, LifeFitness, Illinois, USA) at 70% of heart rate reserve. The target heart rate was calculated using the Karvonen method [37] and the researcher monitored the heart rate remotely with the Polar H10 (Polar Electro Oy, Kempele, Finland). Before the start of the video, the participant had a ten-minute warm-up to reach the target heart rate gradually. After, the participant was asked to cycle between 70 and 90 revolutions per minute. The researcher adjusted the resistance to maintain the target heart rate throughout the 30 minutes of video watching.

Measurements

Perceived workload

The mental load was assessed using the NASA Task Load Index apps (NASA-TLX; NASA, apps), a mental workload assessment tool developed by NASA to evaluate the perceived workload of individuals while performing [38]. It is a multifaceted assessment that measures six dimensions: mental demand, physical demand, temporal demand, performance, effort, and frustration. Each size is rated on a scale of 0-100, with higher scores indicating greater perceived mental load. The participants were asked to fill out the form after the video watching task (T2) and at the end of the examination task (T3). This sequence was reproduced for each condition.

Anxiety

Anxiety was measured using the Tension-Anxiety dimension from a validated French version of the Profile of Moods and State (POMS) [39,40]. The self-report questionnaire (POMS-F) measures five dimensions of mood: Tension-Anxiety, Depression-Dejection, Anger-Hostility, Vigor-Activity, and Fatigue-Inertia. The tension-Anxiety dimension consists of 9 questions, and each question is rated on a 5-point scale, with higher scores indicating a greater intensity of the measured mood state. The participants were asked to fill out the form before (T1) and after (T2) the video and at the end of the examination task (T3). This sequence was reproduced for each condition.

Selective visual attention

Selective visual attention was assessed using Tobii Glasses 2, specifically designed to track and record eye movements and gaze patterns in real time. The eye gaze data were captured at a rate of 100 Hz. Eye movement and gaze data were analyzed using Tobii Pro Lab (Version 1.138 Danderyd, Sweden: Tobii Pro AB) with the attention filter Tobii's I-VT [41]. Each fixation in the area of interest (AOI) was first autonomously tracked using the Tobii Pro analyzer. The area of the iPad surface was defined AOIs. Then, a manual review and corrections were made by the first author. The analyses were done for the length of the 30-minute videos.

Exam score

For each condition, the participant completed an online exam related to the episode viewed. The examinations were composed of multiple choices and short-answer questions developed to have the same difficulty level between the exams. For each exam, a research assistant created a correction booklet with a score of 10 points. The exams were then corrected by the first author following the booklets produced.

Statistical analyses

The study presents all data as mean and standard deviation (SD) unless otherwise specified. The anxiety state variables (POMS-F) were analyzed with an ANOVA for repeated measures (factor time and condition). In the case of interaction, analysis was done by fixing time to compare conditions and fixing condition to compare times with pairwise comparisons using Bonferroni correction. A One-way ANOVA was used to assess the difference between conditions for the perceived workload, exam score and heart rate variables with pairwise comparisons with Bonferroni correction between conditions if necessary. Considering the presence of missing data for selective visual attention, a mixed model ANOVA was conducted with a Bonferroni post-hoc for pairwise comparison between conditions if necessary. Data was considered "missing at random" when the recording of the Tobii Glasses 2 eye-tracker stopped unexpectedly concurrent with an intervention or if the gaze sample (i.e., quality of the eye gaze recording) was below a threshold of 70% [42]. All analyses were performed using SPSS (IBM Corp. Released

2021. IBM SPSS Statistics for Windows, Version 28.0. Armonk, NY: IBM Corp version) with a significance level of 0.05.

Result

Participants

Twenty-four students (67% female) were included in this study. Mean age has 23.0 (3.6) years, height of 167.9 (9.5) cm, body weight of 66.7 (23.5) kg and body mass index of 23.2 (6.2) kg/m^2. Fourteen participants (58.3%) reported doing less than 150 minutes of physical activity per week. Participants reported a mean of 7.4 hours (1.0) of sleep per night and 3.0 (1.9) hours per day of screen time for leisure activities. Fifteen students (62.5%) were undergrads, while the others were all graduated students. Twenty participants (83.3%) reported good to excellent academic results, while eleven participants (45.8%) reported experiencing performance stress due to academic achievement. Ten participants (41.7%) reported experiencing significant stress daily. Also, ten participants (41.7%) reported little or no ability to control their stress.

Physical activity intensity

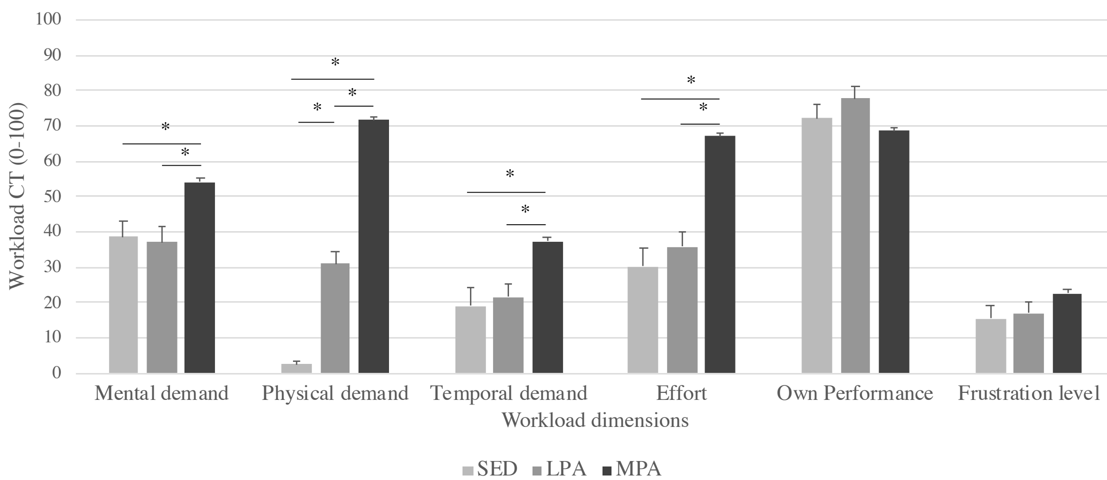
Mean heart rate was analyzed between T1 and T2 (see Fig. 1) and was different between all conditions [$F (2,34) = 388.32$, $p < 0.001$, $\eta2= 0.96$]. Specifically, the average heart rate was 79.5 (11.7) beats per minute for SED, 96.5 (12.5) beats per minute for CD_{LPA} (i.e., 21.8% (7.1%) of maximal heart rate) and 153.8 (6.3) beats per minute for CD_{MPA} (i.e., 66.0% (4.7%) of maximal heart rate).

Perceived workload

Overall perceived workload following the dual-task was significantly different between conditions [$F (2,46) =40.51$, $p< 0.001$; $\eta2= 0.638$], with a higher perceived workload for CD_{MPA} compared to CD_{LPA} [284.0 (90.5) vs.168.1 (78.2); $p<0.001$] and for CD_{MPA} compared to SED [284.0 (90.5) vs.134.0 (72.7); $p<0.01$]. NASA-TLX subscales were also analyzed (see Fig.2). Results showed statistical differences between conditions for the mental demand [$F (2,46)=6.976$, $p=0.02$; $\eta2=0.233$], the physical demand [F (2,46)

=155,695, p<0.001; η2=0.871], the temporal demand [F (2,46) =33.956, p<0.001; η2=0.596] and the perceived effort [F (2,46) =33.956, p<0.001; η2=0.59]. No conditions effect was founded for the own performance [F (2,46) =1.297; p=0.283; η2=0.053] and for frustration level [F (2,46) =1.216; p=0.306; η2=0.050] subscales. Post-hoc analysis showed a higher mental demand score for CD_{MPA} compared to CD_{LPA} (p=0.014) and for CD_{MPA} compared to SED (p=0.021). Physical demand was higher for CD_{MPA} compared to CD_{LPA} (p<0.001), for CD_{MPA} compared to SED (p<0.001) and for CD_{LPA} compared to SED (p<0.001). Temporal demand was higher for CD_{MPA} compared to CD_{LPA} (p=0.005) and for CD_{MPA} compared to SED (p<0.001). Effort was higher for CD_{MPA} compared to CD_{LPA} (p<0.001) and for CD_{MPA} compared to SED (p<0.001).

Figure 2. Perceived subscales workload following the concurrent tasks

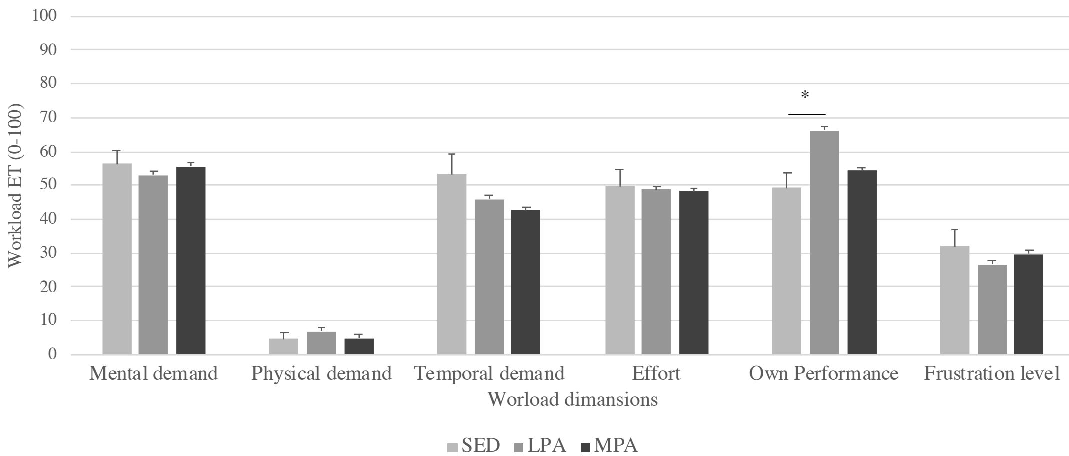


*Workload CT: workload following concurrent tasks, SED: sitting, LPA: cycling desk at low-intensity, MPA cycling desk at moderate intensity; * pairwise significant difference p<0.05, Data are presented as mean scores +/- standard error*

Following the examination task, the overall perceived workload was not different between conditions [F (2,44) =1.874; p=0.166; η2=0.078]. Analyses from subscales showed significant differences between conditions for the perception of own performance only [F (2,44) =5.706, p=0.006; η2=0.206] (see Fig.3). No differences were found for the mental demand [F (2,44) =0.282; p=0.756; η2=0.013], for the physical demand [F (2,44) =1,062; p=0.355; η2=0.046], for the temporal demand [F (2,44) =1.713; p=0.192; η2=0.072], for the perceived effort F(2,44)= 0.061; p=0.941; η2=0.003] and the frustration level [F (2,44)

=0.553; p=0.579, η2=0.025]. Moreover, post-hoc analysis for the perceived own performance showed a higher perception of performance for the CD_{LPA} compared to the SED condition (p=0.005).

Figure 3. Perceived subscales workload following the examination task



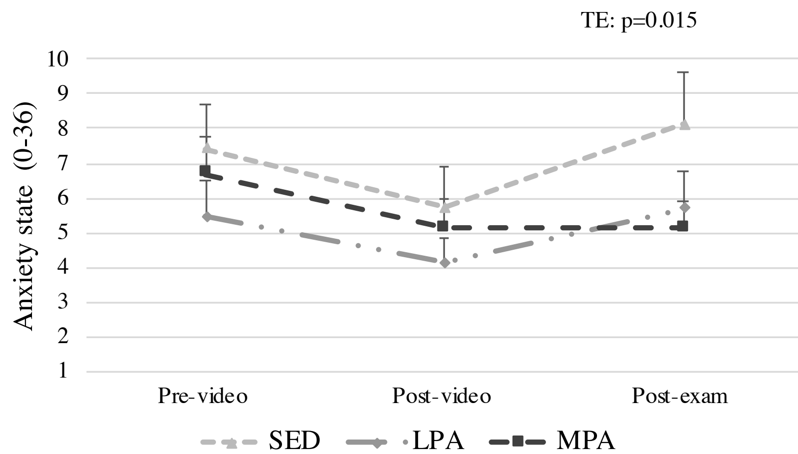
*Workload ET: workload following examination task, SED: sitting, LPA: cycling desk at low-intensity, MPA cycling desk at moderate intensity; * significant difference p<0.05, Data are presented as mean scores +/- standard error*

Anxiety

The analysis of the POMS-F (tense-anxiety dimension questionnaire) showed no significant interaction (condition x time) (p=0.373; η2=0.047). However, a significant time effect was found [F (2,44) = 4.63, p = 0.015; η2= 0.17] revealing an increase in levels over time (see Fig.4). Analyses were also conducted for each question of the anxiety dimension questionnaire (see Figure 4). For the restless level, a Conditions-Time interaction [F (4,88) =4.34, p<0.003); η2=0.16] was observed. Post-hoc analysis revealed that restless level for MPA was higher at T1 compared to T3 (p=0.007) and at T2 compared to T3 (p =0.012). For the nervous level, a Conditions-Time interaction [F (4,88) =2.77; p=0.036); η2=0.18] was also observed. The nervous level at T1 was higher for MPA compared to LPA (p=0.048). Independently of the conditions, time effects were observed for many questions. A time effect was observed (see Fig. 5) for the tense level and shaky level [F (2,44) =9.31, p<0.001; η2=0.29]; [F (2,44) =7.56, p<0.001; η2=0.25], as well for the panickily level and the anxious level [F (2,44) =4.84, p = 0.013; η2= 0.18]; [F (2,44) =5.96, p=0.005; η2=0.21].

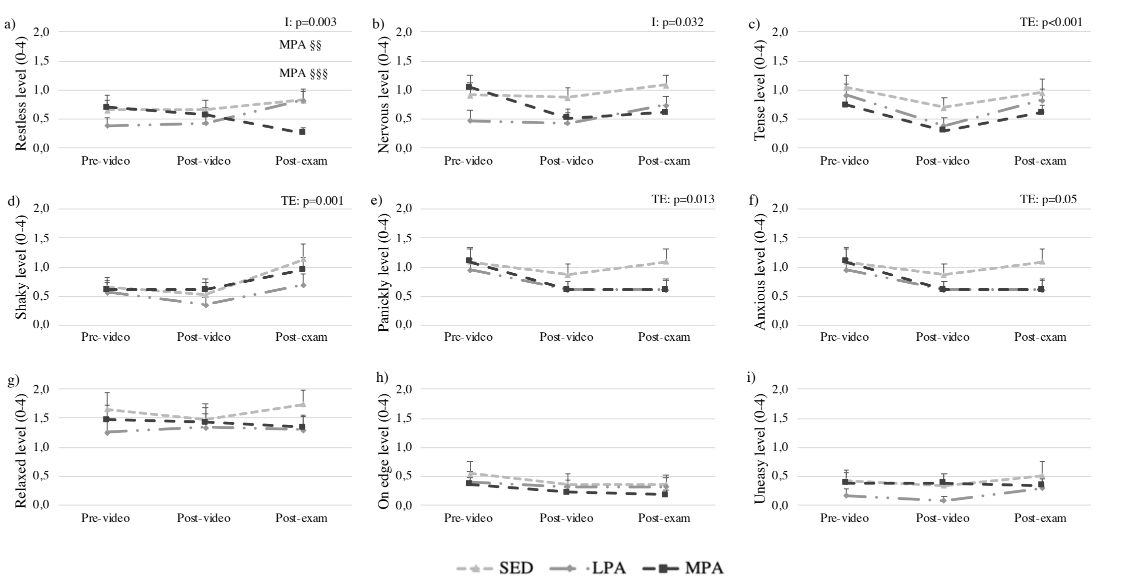
The relaxed, on edge, and uneasy levels were without significant interaction or time effect (See Fig. 6).

Figure 4. Anxiety state (conditions x times)



SED: sitting, LPA: cycling desk at low-intensity, MPA cycling desk at moderate intensity, Data are presented as mean scores +/- standard error, I: Interaction p<0.05, TE: time-effect p<0.05

Figure 5. Anxiety levels (conditions x times)



SED: sitting, LPA: cycling desk at low-intensity, MPA cycling desk at moderate intensity, Data are presented as mean scores +/- standard error, I: Interaction p<0.05, TE: time-effect p<0.05, Bonferroni post-hoc §:p<0.05 T1 vs T2, §§:p<0.05 T2 vs T3, §§§:p<0.05 T1 vs T3, #:p<0.05 SED vs LPA, ##:p<0.05 LPA vs MPA ,###:p<0.05 SED vs MPA

Selective visual attention and exam scores

Selective visual attention results from the eye-tracking glasses showed a significant difference between conditions [F (2, 38.65) =23,042; p<0.001]. Specifically, the average percentage of attention to the video was higher for SED compared to CD_{MPA} [68.86% (17.14) vs. 47.3% (12.45), p<0.001] and higher for CD_{LPA} compared to CD_{MPA} [74.54% (13.35) vs. 47.3% (12.45); p<0.001]. There was no difference between SED and CD_{LPA} (p=0.510). Exam results also differed between conditions [F (2,46) =5.197; p=0.009; $\eta 2$=0.184). The mean exam score (/10) was significantly higher for CD_{LPA} compared to CD_{MPA} [8.08 (0.96) vs. 6.94 (2.24); p=0.033]. No significant differences were observed for CD_{MPA} compared to SED [7.69 (1.30) vs. 6.94 (2.24); p=0.229] either for CD_{LPA} compared to SED [8.08 (0.96) vs. 7.69 (1.30); p=0.328].

DISCUSSION

This randomized cross-over study investigates the impact of cycling desk (LPA and MPA) on perceived workload, anxiety and selective visual attention. The aim of the study is to provide new insights into the effects of integrating physical activity concurrent with academic learning tasks on cognitive and emotional factors in university students. First, although participants experienced greater physical demand while completing the CD_{LPA} compared to the SED condition, selective visual attention and exam scores were similar for the CD_{LPA} to the SED condition. In addition, the anxiety state through CD_{LPA} did not seem to be affected compared to the SED condition. Those findings suggest that university students have the potential to reduce their daily sedentary time without compromising their memorization performance by utilizing a CD_{LPA} while completing academic tasks. However, the second part of our study suggests that the CD_{MPA} induces too much physical demand, which could have a negative impact on mental and temporal demand and require an effort too high to be effective during a study task. Despite the significant amount of PA concurrent with the cognitive task (i.e., 30 minutes at MPA), significant decreases were observed in selective visual attention compared to CD_{LPA} and SED conditions. In addition, exam scores were lower for the CD_{MPA} compared to the CD_{LPA} condition. No significant effect on anxiety state was found. Based on those results, cycling desk at MPA concurrent with an academic learning task should not be encouraged.

Cycling desk at low-intensity

The literature provides insight into the potential benefits of light-intensity physical activity interventions in schools. Specifically, to university students, authors have observed increased arousal and reduced fatigue among university students during class [43]. In our study, CD_{LPA} use concurrently with a memorization task such as video memorizing reduced sedentary time while maintaining memorization performance (i.e., exam score) at a similar level to sedentary work (i.e., average exam score [LPA 8.08 (0.96) vs. SED 7.69 (1.30)]. These results are consistent with the current literature, which showed with LPA exercise intensity that, cognitive performance is not detrimental to the use of the cycling desk [27,44]. Considering those findings, CD_{LPA} could be a useful tool to break sedentary behaviour without compromising academic performance.

To the best of our knowledge, no prior research has investigated the impact of using a CD_{LPA} on selective visual attention using eye-tracking technology. The study hypothesis was that selective visual attention, measured by fixation time on a video, would be higher during CD_{LPA} compared to a SED condition. In fact, a previous study observed pupil dilation with LPA intensity, which positively correlated with psychological arousal increases [45]. However, our findings indicated no difference in selective visual attention between the CD_{LPA} and the SED condition [LPA 74.54% (13.35) vs. SED = 68.86% (17.14), p=0.510]. The low-intensity cycling desk may not be enough to produce perceptual benefits (i.e., higher fixation time) in complex attentional demand tasks, such as watching a 30-minute video. Actual studies with similar (n=23) or smaller (n=10) sample sizes using neuropsychologic measurements such as reaction time in detection task and working memory task fund significant differences with large effect size in support of the cycling desk compare to sitting work [29,30]. Since selective visual attention plays a crucial role in memorization and is closely linked with learning [46,47] a protocol using both neuropsychologic test and eye-tracking measurement could be of interest to determine the impact of CD_{LPA} on selective and sustain attention. This study serves as an initial step in exploring the effects of low-intensity cycling with an eye-tracking device on visual attention processes.

When using the CD_{LPA}, the perceived workload increased compared to the sedentary condition due to physical demand. These results are consistent with a current study [48] and show the effect of physical demand concomitant with a cognitive task on workload, even with low physical intensity. The results also indicate that the perceived workload at the end of the examination period was similar in the CD_{LPA} and SED conditions. Therefore, the increase in physical demand due to low intensity was punctual to the dual-task and no deterioration in the subsequent task workload was observed. In fact, the result following the examination period showed a better perception of their performance for CD_{LPA} compared to the SED condition ($p = 0.005$). They are aligned with previous studies that showed increased arousal and wakefulness throughout the workday using CD_{LPA} [25,28]. Therefore, our study suggests that CD_{LPA} may positively impact perceived performance/satisfaction throughout the day.

The current findings revealed that the use of a CD_{LPA} did not result in any significant difference in anxiety state compared to traditional sitting work. Both the SED and CD_{LPA} conditions showed a decreased anxiety while listening to the video, followed by an increase during the examination period. However, a closer look at each question of the POMS-F questionnaire showed that the mean anxiety level after the examination period was slightly higher in the SED condition (1.09 ± 1.0) compared to the LPA condition (0.61 ± 0.8), with a p-value of 0.054. The findings imply that CD_{LPA} may have the potential to reduce anxiety, which is consistent with a prior study that found university students to feel more at ease and relax while using a cycling desk in lecture tasks [49,50]. However, due to the small sample size (n=24), the hypothesis cannot be concluded with certainty. This study opens new insights into the combined effects of CD_{LPA} and acute mental tasks anxiety state during academic task simulations. Overall, while the current findings suggest that using cycling desks may impact anxiety levels during academic tasks, additional research using similar questionnaires with larger sample sizes and randomized control trials may be necessary to confirm our hypothesis.

Cycling desk at moderate-intensity

Growing evidence supports the benefit of moderated physical activity on executive function [18]. Shorts bouts of moderate physical activity may enhance attention, awareness, and memorization [51]. Unexpectedly, this study suggests that cycling in moderate intensity concurrent with an attention task such as video memorizing decreases memorization performance compare to SED and CD_{LPA} (i.e., average exam score) [CD_{MPA} 6.94 (2.24) vs. CD_{LPA} 8.08 (0.96) vs. SED 7.69 (1.30)]. The results suggest that the physical demand level combined with the video visualization task decreased the video fixation durations. The deterioration of selective visual attention could thus be related to poor performance in the examination task.

Our hypothesis was based on previous research that found that a moderate-intensity exercise concomitant to a cognitive task can enhance arousal, reaction time and switching task [52,53]. Therefore, we hypothesized that participants who engaged in a cycling moderate-intensity exercise would have greater fixation time while watching a video than those who remained sedentary. However, the results of our study indicate a significant decrease in visual attention on the video viewing task while cycling in CD_{MPA} [68.86% (17.14) vs. 47.3% (12.45), $p<0.001$]. Studies conducted with bicycle couriers have shown that a high physical demand level can lead to decreased cognitive performance, such as detecting environmental stimuli [54,55]. Thus, the dual-task involving moderate physical intensity on the cycling desk may not be advisable during a memory task such as studying for an exam. During the concurrent task of cycling and video watching, the overall perceived workload of the participants was must higher in the CD_{MPA} condition compared to the SED and the CD_{LPA} condition. The mental, physical, temporal and effort demands were the main demands explaining the overall increase. Our findings show that greater physical demands can lead to a mental and effort burden. A previous study has also observed similar results with decreased mathematical operations tasks [48] when the perceived workload is too high. According to Basahel, Young [56], there appears to be an optimal range of physical and cognitive exertion that yields the highest performance outcomes. These authors indicate that performance tends to deteriorate at both low and high levels of physical and mental demand. In summary, our results suggest that engagement in CD_{MPA} could elevate perceived workload compared to both sedentary (SED) and CD_{LPA} conditions and potentially lead to detrimental effects on memorization tasks undertaken during physical activity.

In this study, cycling at CD_{MPA} did not significantly impact the anxiety state compared to conventional sitting work. Anxiety levels decreased while participants watched the video, regardless of whether they were cycling or sitting. However, the anxiety score showed a declining trend towards the end of the examination period in the CD_{MPA} condition compared to the SED condition. Moderate physical activity may have a light effect on the overall POMS-F scores. Although previous evidence suggests that moderate exercise can reduce anxiety levels [57], it remains unclear whether anxiety can be modulated differently during dual-tasks that involve moderate physical activity. Therefore, the current study findings suggest that CD_{MPA} exercise has a limited impact on psychological well-being during or after studying and examination tasks compared to sitting work or CD_{LPA}.

Strengths and limitations

Considering the mental health and performance anxiety issues in the university student population, our study provides new insight into the influence of different intensities of physical activity concurrent with an academic task such as studying. Although, some limitations should be mentioned in our study. First, the target heart rates for the light and moderate intensity were based on an estimation calculation. While the statistical analysis indicates that we are within the range of intensity differences, the measurement of maximal heart rate during a stress test would strengthen the measurement of the intensities and enhance the precision of our intervention. Also, among the participants, three reported a diagnosis of anxiety disorders, two reported an ADHD diagnosis, two reported a combined diagnosis of ADHD and anxiety disorders, and one reported a diagnosis of anxiety disorder with a diagnosis of depression. However, the sample size was not large enough to conduct these analyses. Sensitivity analyses were performed to ensure that the inclusion of the 6 participants did not change the results, which was the case. This study represents a first step and subsequent studies should use the current finding to analyze in detail if students with greater needs can beneficiate from CD_{LPA} or CD_{MPA}. Furthermore, the data collected in this study can serve as a valuable basis for estimating the targeted sample size in subsequent protocols.

Conclusion

With the goal of increasing PA levels in university students to enhance academic achievement and well-being, using a cycling desk would be a tool to consider. The results suggest an increase in test scores in the CD_{LPA} condition compared to the CD_{MPA} condition. This result is consistent with greater visual attention of the participants watching the video in the CD_{LPA} than in the CD_{MPA}. In addition, CD_{MPA} induced more mental load without direct benefits for anxiety. Cycling desk concurrent with an attention task such as video memorizing decreases daily sedentary time while maintaining memorization performance similar to sedentary mental work. Findings support that simple use of a cycling desk could be interesting to lower sedentary behaviours at school without impairing the learning process, while moderate intensity is to be proscribed.

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Declarations of interest none

References

1. Carballo-Fazanes A, Rico-Díaz J, Barcala-Furelos R, et al. Physical Activity Habits and Determinants, Sedentary Behaviour and Lifestyle in University Students. International Journal of Environmental Research and Public Health. 2020 [cited. DOI:10.3390/ijerph17093272
2. Thomas AM, Beaudry KM, Gammage KL, et al. Physical Activity, Sport Participation, and Perceived Barriers to Engagement in First-Year Canadian University Students. Journal of Physical Activity and Health.16(6):437-446.
3. Castro O, Bennie J, Vergeer I, et al. How Sedentary Are University Students? A Systematic Review and Meta-Analysis. Prevention Science. 2020 2020/04/01;21(3):332-343.
4. Katie A Weatherson, Himabindu Joopally, Kelly Winderlich, et al. Post-secondary students' adherence to the Canadian 24-Hour Movement Guidelines for Adults: Results from the first deployment of the Canadian Campus Wellbeing Survey (CCWS). Health Promotion and Chronic Disease Prevention in Canada. 2021;41(6).
5. Rachel C. Colley, Justin J. Lang, Travis J. Saunders, et al. How sedentary are Canadian adults? It depends on the measure. Statistics Canada; 2022.
6. Garn AC, Simonton KL. Prolonged Sitting in University Students: An Intra-Individual Study Exploring Physical Activity Value as a Deterrent. Int J Environ Res Public Health. 2023 Jan 19;20(3).
7. Dunstan DW, Howard B, Healy GN, et al. Too much sitting – A health hazard. Diabetes Research and Clinical Practice. 2012 2012/09/01/;97(3):368-376.
8. Lee E, Kim Y. Effect of university students' sedentary behavior on stress, anxiety, and depression [https://doi.org/10.1111/ppc.12296]. Perspectives in Psychiatric Care. 2019 2019/04/01;55(2):164-169.
9. Tan SL, Jetzke M, Vergeld V, et al. Independent and Combined Associations of Physical Activity, Sedentary Time, and Activity Intensities With Perceived Stress Among University Students: Internet-Based Cross-Sectional Study. JMIR Public Health Surveill. 2020 Nov 11;6(4):e20119.
10. Epstein I, Khanlou N, Balaquiao L, et al. University Students' Mental Health and Illness Experiences in Health and Allied Health Programs: A Scoping Review. International Journal of Mental Health and Addiction. 2019 2019/06/01;17(3):743-764.
11. Duffy A, Keown-Stoneman C, Goodday S, et al. Predictors of mental health and academic outcomes in first-year university students: Identifying prevention and early-intervention targets. BJPsych Open. 2020;6(3):e46.
12. Canadian Society for Exercise Physiology. Canadian 24-Hour Movement Guidelines for Adults aged 18-64 years: An Integration of Physical Activity, Sedentary Behaviour, and Sleep. Ottawa, Canada: Canadian Spciety for excercese physoilogy; 2021.
13. Piercy KL, Troiano RP, Ballard RM, et al. The Physical Activity Guidelines for Americans. JAMA. 2018;320(19):2020-2028.

14. Kljajević V, Stanković M, Đorđević D, et al. Physical Activity and Physical Fitness among University Students-A Systematic Review. International journal of environmental research and public health. 2021;19(1):158.
15. Moulin MS, Truelove S, Burke SM, et al. Sedentary time among undergraduate students: A systematic review. Journal of American College Health. 2021 2021/04/03;69(3):237-244.
16. Bray SR, Born HA. Transition to University and Vigorous Physical Activity: Implications for Health and Psychological Well-Being. Journal of American College Health. 2004 2004/01/01;52(4):181-188.
17. Ferro EF, Cid FM, Munoz HD, et al. Effects of a session of physical exercise on the neurophysiological activity during the resolution of a test of selective attention [Article]. Retos. 2019 (36):391-397.
18. Diamond A, Ling DS. Review of the Evidence on, and Fundamental Questions About, Efforts to Improve Executive Functions, Including Working Memory. 2019 [cited 3/9/2023]. In: Cognitive and Working Memory Training: Perspectives from Psychology, Neuroscience, and Human Development [Internet]. Oxford University Press, [cited 3/9/2023]; [0]. Available from: https://doi.org/10.1093/oso/9780199974467.003.0008.
19. Vazou S, Skrade MAB. Intervention integrating physical activity with math: Math performance, perceived competence, and need satisfaction. International Journal of Sport and Exercise Psychology. 2017 2017/10/20;15(5):508-522.
20. Ferreira Silva RM, Mendonça CR, Azevedo VD, et al. Barriers to high school and university students' physical activity: A systematic review. PLoS One. 2022;17(4):e0265913.
21. Pellerine LP, Bray NW, Fowles JR, et al. The Influence of Motivators and Barriers to Exercise on Attaining Physical Activity and Sedentary Time Guidelines among Canadian Undergraduate Students. INTERNATIONAL JOURNAL OF ENVIRONMENTAL RESEARCH AND PUBLIC HEALTH. 2022 OCT;19(19).
22. Deliens T, Deforche B, De Bourdeaudhuij I, et al. Determinants of physical activity and sedentary behaviour in university students: a qualitative study using focus group discussions. BMC Public Health. 2015 2015/02/28;15(1):201.
23. Tomporowski PD, Qazi AS. Cognitive-Motor Dual Task Interference Effects on Declarative Memory: A Theory-Based Review [Review]. Frontiers in Psychology. 2020 2020-May-26;11(1015).
24. Guirado T, Chambonniere C, Chaput JP, et al. Effects of Classroom Active Desks on Children and Adolescents' Physical Activity, Sedentary Behavior, Academic Achievements and Overall Health: A Systematic Review. Int J Environ Res Public Health. 2021 Mar 10;18(6):2828.
25. Torbeyns T, de Geus B, Bailey S, et al. The potential of bike desks to reduce sedentary time in the office: a mixed-method study. Public Health. 2017 2017/03/01/;144:16-22.
26. Podrekar N, Kozinc Ž, Šarabon N. Effects of cycle and treadmill desks on energy expenditure and cardiometabolic parameters in sedentary workers: review and meta-analysis. International Journal of Occupational Safety and Ergonomics. 2021 2021/07/03;27(3):728-736.

27. Podrekar N, Kozinc Ž, Šarabon N. The effects of cycle and treadmill desks on work performance and cognitive function in sedentary workers: A review and meta-analysis. Work. 2020;65:537-545.
28. Sliter M, Yuan Z. Workout at work: laboratory test of psychological and performance outcomes of active workstations. J Occup Health Psychol. 2015 Apr;20(2):259-71.
29. Torbeyns T, de Geus B, Bailey S, et al. Cycling on a Bike Desk Positively Influences Cognitive Performance. PLoS One. 2016;11(11):e0165510.
30. Mullane SL, Buman MP, Zeigler ZS, et al. Acute effects on cognitive performance following bouts of standing and light-intensity physical activity in a simulated workplace environment. Journal of Science and Medicine in Sport. 2017 2017/05/01/;20(5):489-493.
31. Tronarp R, Nyberg A, Hedlund M, et al. Office-Cycling: A Promising Way to Raise Pain Thresholds and Increase Metabolism with Minimal Compromising of Work Performance. BioMed Research International. 2018 2018/01/23;2018:5427201.
32. Chaytor N, Schmitter-Edgecombe M. The Ecological Validity of Neuropsychological Tests: A Review of the Literature on Everyday Cognitive Skills. Neuropsychology Review. 2003 2003/12/01;13(4):181-197.
33. Rubio-Valdehita S, López-Higes R, Díaz-Ramiro E. Academic Context and Perceived Mental Workload of Psychology Students. The Spanish Journal of Psychology. 2014;17:E53.
34. Beiter R, Nash R, McCrady M, et al. The prevalence and correlates of depression, anxiety, and stress in a sample of college students. Journal of Affective Disorders. 2015 2015/03/01/;173:90-96.
35. Ciria LF, Román-Caballero R, Vadillo MA, et al. An umbrella review of randomized control trials on the effects of physical exercise on cognition. Nature Human Behaviour. 2023 2023/03/27.
36. Craig CL, Marshall AL, SjÖStrÖM M, et al. International Physical Activity Questionnaire: 12-Country Reliability and Validity. Medicine & Science in Sports & Exercise. 2003;35(8).
37. Karvonen MJ, Kentala E, Mustala O. The effects of training on heart rate; a longitudinal study. Ann Med Exp Biol Fenn. 1957;35(3):307-15.
38. Hart SG, editor NASA-task load index (NASA-TLX); 20 years later. Proceedings of the human factors and ergonomics society annual meeting; 2006: Sage publications Sage CA: Los Angeles, CA.
39. Cayrou S, Dickès P, Dolbeault S. Version française du profile of mood states (POMS-f). [French version of the Profile Of Mood States (POMS-f).]. Journal de Thérapie Comportementale et Cognitive. 2003;13(2):83-88.
40. Cayrou S, Dickes P, Gauvain-Picquard A, et al. Validation de la traduction française du Profile of Mood States (POMS). Psychol Psychom. 2000 01/01;21:5-22.
41. Tobii Studio. When do I use the I-VT Attention filter? 2018 [cited 2023 01/05/2023]. Available from: https://connect.tobii.com/s/article/When-do-I-use-the-I-VT-Attention-filter?language=en_US

42. Tobii Studio. How is the sample percentage calculated in Studio, Lab and Controller? 2018 [cited 2023 01/05-2023]. Available from: https://connect.tobii.com/s/article/Sample-percentage-calculated-in-Studio-Lab-and-Controller?language=en_US
43. Polo-Recuero B, Rojo-Tirado MÁ, Ordóñez-Dios A, et al. The Effects of Bike Desks in Formal Education Classroom-Based Physical Activity: A Systematic Review. Sustainability. 2021;13(13):7326.
44. Joubert L, Kilgas M, Riley A, et al. In-Class Cycling to Augment College Student Academic Performance and Reduce Physical Inactivity: Results from an RCT. International Journal of Environmental Research and Public Health. 2017;14(11):1343.
45. Kuwamizu R, Yamazaki Y, Aoike N, et al. Pupil-linked arousal with very light exercise: pattern of pupil dilation during graded exercise. The Journal of Physiological Sciences. 2022 2022/09/24;72(1):23.
46. Lussier F, Chevrier E, Gascon L. Chapitre 4. Attention et mémoire, deux autres voies d'accès à l'apprentissage. Neuropsychologie de l'enfant et de l'adolescent. Paris: Dunod; 2018. p. 209-246.
47. Fisher AV. Selective sustained attention: a developmental foundation for cognition. Current Opinion in Psychology. 2019 2019/10/01/;29:248-253.
48. DiDomenico A, Nussbaum MA. Interactive effects of physical and mental workload on subjective workload assessment. International Journal of Industrial Ergonomics. 2008 2008/11/01/;38(11):977-983.
49. Bastien Tardif C, Cantin M, Sénécal S, et al. Implementation of Active Workstations in University Libraries—A Comparison of Portable Pedal Exercise Machines and Standing Desks. International Journal of Environmental Research and Public Health. 2018;15(6):1242.
50. Ruiter M, Loyens S, Paas F. The Effects of Cycling on a Desk Bike on Attention, Retention and Mood during a Video Lecture [https://doi.org/10.1002/acp.3355]. Applied Cognitive Psychology. 2017 2017/11/01;31(6):593-603.
51. de Greeff JW, Bosker RJ, Oosterlaan J, et al. Effects of physical activity on executive functions, attention and academic performance in preadolescent children: a meta-analysis. Journal of Science and Medicine in Sport. 2018 2018/05/01/;21(5):501-507.
52. McMorris T, Tomporowski P, Audiffren M. Exercise and Cognitive Function. Chichester: John Wiley & Sons; 2009. Available from: http://www.123library.org/book_details/?id=4164
53. Lambourne K, Tomporowski P. The effect of exercise-induced arousal on cognitive task performance: A meta-regression analysis. Brain Research. 2010 2010/06/23/;1341:12-24.
54. Theurel J, Theurel A, Lepers R. Physiological and cognitive responses when riding an electrically assisted bicycle versus a classical bicycle. Ergonomics. 2012 2012/07/01;55(7):773-781.
55. Boele-Vos MJ, Commandeur JJF, Twisk DAM. Effect of physical effort on mental workload of cyclists in real traffic in relation to age and use of pedelecs. Accident Analysis & Prevention. 2017 2017/08/01/;105:84-94.

56. Basahel AM, Young MS, Ajovalasit M. Impacts of physical and mental workload interaction on human attentional resources performance. Proceedings of the 28th Annual European Conference on Cognitive Ergonomics; Delft, Netherlands: Association for Computing Machinery; 2010. p. 215–217.
57. Ensari I, Greenlee TA, Motl RW, et al. META-ANALYSIS OF ACUTE EXERCISE EFFECTS ON STATE ANXIETY: AN UPDATE OF RANDOMIZED CONTROLLED TRIALS OVER THE PAST 25 YEARS. Depression and Anxiety. 2015;32(8):624-634.