Energy intake and food preferences following low and moderate intensities of cycling desk concurrent to academic task – When too high is detrimental to nutritional quality

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Abstract

The rising prevalence of sedentariness in academic settings highlights the need to explore alternative strategies, such as using active desks. This study assesses cycling desks' effects using light (LPA) and moderate (MPA) intensities of physical activity compared to a conventional seated desk (SIT) on energy intake and food preferences, including visual fixation time of food. Participants (n=18) underwent a randomized crossover protocol where SIT, LPA and MPA were used while performing academic tasks. Energy and macronutrient intakes were assessed via an ad-libitum buffet. Preferences were recorded across five food categories (low-fat sweet, high-fat sweet, low-fat savoury, high-fat savoury, and fat) according to ingestion and eye fixation monitored using Tobii Glasses 2 (100Hz). Statistical analysis was conducted using ANOVA with pairwise comparisons with a significant threshold of $p<0.05$. Results showed no significant differences in overall energy and macronutrient intakes across the conditions (all p values > 0.05). There was a significant difference in intake of low-fat sweet foods between the conditions ($p=0.040$), with pairwise analysis revealing that the MPA condition was almost significantly higher than SIT [295(198) vs. 208 (149) grams, respectively; $p=0.053$). This difference appears attributable to an increase in sweetened beverages 173 (196) grams vs. 68 (124) grams; $p=0.046$). Eye-tracking technology showed that total fixation time on different food categories was consistent across conditions. In conclusion, while using cycling desks did not alter overall energy intake, MPA did increase the consumption of low-fat sweet foods via increased sugar-sweet beverages compared to standard desk condition.

Keywords: Cycling desk; Energy Intake, Food Preferences

Introduction

The rise of sedentary behaviors is a growing concern in modern times (Straker et al., 2016) and does not spare the academic community (Faghy et al., 2022; López-Olivares et al., 2021). According to a meta-analysis of 32 studies (n=23,757), 49% of university students spend more than 6 hours daily in sedentary activities, while 31% spend more than 8 hours daily (Castro et al., 2020). This sedentariness is particularly noteworthy given that body weight gain, ranging from three to 15 pounds during the first year of undergraduate studies, has been well documented (Sharma et al., 2021; Vadeboncoeur et al., 2015).

Tasks requiring sustained attention and information processing increase appetite and food intake (Ampel et al., 2018; Salama et al., 2016), decrease the likelihood to adopting healthy eating behaviors, and increase reliance on processed and fast food (Bárbara & Ferreira-Pêgo, 2020; López-Olivares et al., 2021; Sogari et al., 2018). Additionally, prolonged cognitive work can induce stress, releasing cortisol and raising ghrelin levels, increasing food cravings (Chao et al., 2017). Engaging in cognitively demanding tasks may distract from hunger signals or fullness, which can also influence eating behaviors (Ding et al., 2019; Liguori et al., 2020). Physical activity can help improve appetite, food intake, and eating patterns (Blundell et al., 2015). When performed at higher intensities, it reduces ghrelin levels that stimulate hunger while increasing leptin and peptide YY, contributing to reduced hunger and increased satiety (McCarthy et al., 2020; Zouhal et al., 2019). Changes in these hormones can thus lead to decreased food intake and a preference for low-fat food following physical activity (Beaulieu et al., 2020).

Innovative solutions such as active workstations have emerged to address the challenges of sedentarism . These devices, presented mainly as standing, cycling, and treadmill desks, aim to incorporate physical activity into standard cognitive tasks, promoting active time concurrently with work tasks. Recent research has highlighted the benefits of cycling desks, especially in educational settings such as elementary and high schools (Guirado et al., 2021). While studies haven't yet assessed treadmills in academic settings, cycling desks lead to higher energy expenditure (up to 37%) than standing desks (15-26%) and cause less discomfort among youth (Guirado et al., 2021). Additionally, introducing cycling desks in classrooms has reduced sedentary time by 9.5% (Fedewa et al., 2018) without negatively impacting cognitive functions like memorization (Guirado et al., 2021). These results align with research conducted in workplace environments where cycling desks improved well-being, job satisfaction, energy levels, and alertness while reducing boredom (Ruiter et al., 2017; Sliter & Yuan, 2015). Furthermore, the literature indicates that cycling desks do not compromise productivity compared to traditional seated desks (Podrekar et al., 2020; Rosenkranz et al., 2020).

To our knowledge, only two studies have assessed the relationship between active desks and food consumption. One study from our group evaluated food intake and appetite sensations (hunger and fullness), comparing the seated posture to a standing desk. No difference was found between the two types of desks (Josaphat et al., 2020). The second study, conducted by Thivel's research group, assessed appetite and energy intake while using a low-intensity cycling desk during cognitive tasks. In this case, using a cycling desk during cognitive tasks did not affect appetite sensations. Still, it did result in a 23% increase in energy intake compared to cognitive tasks performed while sitting (Thivel et al., 2021). To date, no study has investigated the impact of active desks when performed above light intensity. To investigate higher intensities, cycling desks are an attractive model because they are more suitable for performing at higher intensity than treadmill desks, where the treadmill might be noisy and interfere with writing tasks (Cifuentes et al., 2015). This higher intensity could be of interest considering that almost all studies recently reviewed yield little or no effect on body composition outcomes for the cycling desk (Guirado et al., 2021; Josaphat et al., 2019)

In this context, the 'Activate Your Brain' project was introduced to university students as part of the Université de Montréal Success Improvement Program. This project first aimed to evaluate various aspects of students' learning abilities, such as perceived workload, anxiety, and visual selective attention via eye-tracking glasses while using cycling desks at low and moderate intensities (Dupont et al., 2023). Given the limited research on the impact of active desks on energy intake, the project also assesses energy intake and food preferences. It also used eye-tracking technology to monitor eye-gaze through lunchtime. This novel approach was recently used to examine and validate information gathered from choosing food in real-life settings (Peng et al., 2021; Wang et al., 2018; Yasui et al., 2019). Considering the growing interest in cycling desks and the complex interplay between physical activity, cognitive load, and eating behaviors, the current study aimed to examine the impact of standard seated position (reference condition) as well as low and moderate intensities using cycling workstations during academic tasks on subsequent dietary intakes and food preferences, including visual fixation time on food.

Method

The study population

The target population of this study was full-time university students aged between 18 to 65 years. Electronic recruitment forms were sent via the student associations and posted on university notice boards. The exclusion criteria were: 1) adhering to a specific diet or regimen; 2) having a diagnosed eating disorder like bulimia or anorexia; 3) taking medications such as insulin, beta-blockers, or corticosteroids; 4) suffering from chronic gastrointestinal issues like Crohn's disease; 5) having food intolerances or allergies; 6) having physical impairments that could hinder physical activity and 7) and having photosensitive epilepsy. The study was carried out in adherence to the ethical certificate #CERC-21-003-P issued by the Clinical Research Ethics Committee of the Université de Montréal. Each participant signed the consent form.

Protocol overview

This randomized crossover study started with an initial virtual meeting where the researchers reviewed the consent form and verified eligibility for the study. A health and lifestyle questionnaire, adapted from the IPAQ questionnaire (Craig et al., 2003), was provided for the participants to complete before their first laboratory session. Each participant was evaluated individually. They were required to attend an experimental session weekly for three visits in randomized order.

Each session began with the participant arriving at the lab at 9:00 a.m. Upon arrival, the researcher fitted the participant with a Polar H10, which monitored the heart rate remotely throughout the session. After this, the participant was asked to consume a standardized breakfast consisting of toasted bread, butter, peanut butter, cheddar cheese, and orange juice. Once they finished their breakfast, the participant moved to a different room and was handed an iPad (8th generation, Apple, CA, USA). They then watched a 30-minute segment from the documentary “Babies 2020” on Netflix. After viewing the video segment, the participant completed an online exam with multiple-choice and short-answer questions for 30 minutes based on the documentary. Finally, a buffet-type lunch was served. Participants were instructed to eat as much as they wanted until satisfied. At the end of the study, they informed that their consumption of the buffet-type meal had been monitored. From 9:15 until the end of each session, they were fitted with a pair of Tobii glasses 2, allowing eye-gaze recording throughout desk time, exam time, and lunchtime. Perceived workload, anxiety, eye-fixation time during the video and the exam, and results at the exam were also assessed and were the subject of another publication available in a preprint version (Dupont et al., 2023) and submitted for peer review.

Desk conditions

In the SIT session, participants sat comfortably at a conventional work desk to watch the 30-minute video. In the LPA session, participants used a cycling desk (ProPlus 36TM, Varidesk, Texas, United States) set at level 3 (approximately 22 watts at 60 revolutions per minute). The participants pedaled at a light and comfortable cadence throughout the video, maintain a stable pedaling cadence, and avoid excessive fatigue or dyspnea. In the MPA session, participants watched the 30-minute video while pedaling a Lifecycle 9500HR Upright bike (LifeFitness, Illinois, USA) to achieve 70% of their heart rate reserve. This heart rate target was established by leveraging the Karvonen formula (Karvonen et al., 1957) and monitored by a Polar H10 (Polar Electro Oy, Kempele, Finland). The session incorporated a ten-minute warm-up period to enable the participant to reach the target heart rate. After this period, he maintained a cycling speed ranging from 70 to 90 revolutions per minute, and the evaluator adjusted the resistance to maintain the target heart rate.

Dietary intakes and food preferences

After an overnight fast, a standardized breakfast was served at the laboratory at the beginning of each session. Participants had to eat it entirely over 15 minutes. A buffet-type meal was offered after each experimental condition. The food and beverage selection was based on a validated buffet-type meal (Arvaniti et al., 2000). The food presentation on the table and in the room was always the same for each meal (see Figure 1). The participants had 30 min to consume food. The instruction given to the participants was to eat until they were satisfied. They were not allowed to use their phones or external distractions. The buffet foods were weighed before and after the meal using an electronic scale (SLF3001-US, Fisher Science Education, Hanover Park, IL, USA). Participants did not have access to water or food outside the meal periods.

Food preferences were calculated and categorized based on a validated and modified version of the Leeds Food Preference Questionnaire proposed by Oustric et al. (2020). Each food was grouped into five categories: low-fat sweet (LFSW), high-fat sweet (HFSW), low-fat savoury (LFSA), high-fat savoury (HFSA), and Fat(Oustric et al., 2020). The total intake in grams of each food in a category represented the value of the category. These categories were used to analyze food preferences and visual fixation time, as illustrated in Figure 1. Food preferences by visual fixation time were also assessed using Tobii Glasses 2 100 Hz (Tobii AB. Wearable eye-tracking system;

https://www.tobiipro.com/), which monitors real-time ocular eye movement and eye fixation. The eye-gaze data were analyzed using Tobii Pro Lab (Version 1.138, Danderyd, Sweden: Tobii Pro AB) with Tobii's I-VT filter. An Area of Interest (AOI) was defined for each food offered at the buffet for analysis purposes. Each eye fixation time within the food AOIs was initially autonomously tracked utilizing the Tobii Pro analyzer and was followed by a thorough review and necessary corrections conducted manually by the first author. The analysis of fixation times on the Tobii analyzer was carried out over the entire duration of the time allocated to participants to eat, and data reported are in percentage of time out of the 30 minutes devoted to meal-time.

Figure 1 Buffet presentation and food categories

Statistical analysis

Data are reported as means (standard deviations), unless otherwise specified. A One-way ANOVA and pairwise comparison with Bonferroni correction between conditions were employed to assess differences for variables such as energy and macronutrient intakes, and food preferences. Due to missing data on food preference visual fixation time, a mixed model ANOVA with pairwise comparisons using Bonferroni was performed between conditions. The data was considered "missing at random" since missing values were obtained when the recording eye-tracker stopped unexpectedly during an intervention or when the quality of the eye gaze recording (i.e., gaze sample) was below a threshold of 70%. All analyses were conducted using SPSS (IBM Corp. Released 2021. Version 28.0. Armonk, NY: IBM Corp version) with a significance level of 0.05.

Results

Eighteen university students (67% female) were included in this study. Average age was 22.4 (3.1) years, height of 166.9 (10.2) cm, body weight of 62.5 (17.3) kg, and body mass index of 22.0 (3.6) kg/m^2. Participants reported an average sleep duration of 7.4 ± 1.2 hours per night and a mean leisure screen time of 2.9 ± 1.9 hours per day. Over half of the participants (57.9%) did not reach a minimum of 150 minutes of moderate to high-intensity physical activity per week.

Total energy intake at lunchtime was not significantly different between SIT, LPA, and MPA conditions [F (2,34) = 1.505; p = 0.236]. Intakes for carbohydrates [F (2, 34) =1.198; p=0.314], lipids [F (2,34) = 1.565; p=0.224], proteins [F (2,34) = 1.203; p=0.313], fibers [F (2,34) = 0.658; p=0.524] and sodium [F (2,34) = 2.760; p=0.77] were also similar between all conditions (Table 1).

Table 1 Energy and macronutrient intakes following desk conditions

Intakes	SIT	LPA	MPA	p-value
Total energy (kJ)	3807 (2985)	3040 (2113)	3684 (2677)	0.236
Carbohydrates (kJ)	1500 (1216)	1192 (754)	1468 (983)	0.314
Lipids (kJ)	1601 (1449)	1237 (1026)	1543 (1293)	0.224
Proteins (kJ)	706 (486)	611 (413)	673 (510)	0.313
Fibers (g)	6.0 (3.2)	5.2 (3.3)	6.1(3.8)	0.524
Sodium (mg)	1518 (1158)	1262 (908)	1508 (1137)	0.077

Results presented are means (standard deviations); kJ: kilojoules; g: grams; mg: milligrams; Statistical difference threshold set at p<0.05; SIT: Sitting condition; LPA: Low-intensity Physical Activity condition; MPA: Moderate-intensity Physical Activity condition

The analyses for food preference fixation times were done with a subsample of n=16. Similar fixation times were shown between desk conditions for all categories of food: LFSW [F (2,28) = 0.737; p=0.487], HFSW [F (2,26) = 0.445; p=0.645], LFSA [F (2,28) = 0.984; p=0.386], HFSA [F (2,27) = 0.050; p=0.951] and Fat [F (2, 27) = 0.006; p=0.994] preferences (Table 2). Nevertheless, food preferences in grams (n=18) showed a significant difference in preferences for LFSW foods between the conditions [F (2,34) = 3.532; p=0.040] (Table 3). Pairwise analysis almost reach significance between MPA [295 (199) grams] and SIT condition [208(149) grams] (p=0.053). Similar results were obtained when the analysis was replicated with the subsample used for the fixation duration time (n=16) (data not presented). The average sweet drink consumption was different between conditions (p=0.015). The MPA 173 (196) grams of sweet drink was higher than LPA [67(121) grams (p=0.061)] and compare to SIT [68 (124) grams] conditions (p=0.046).

Table 2 Food preference fixation time at lunchtime following desk conditions

Food categories	% Fixation time			p-value
	SIT	LPA	MPA	
Low fat & sweet	1.40 (1.09)	1.04 (0.66)	2.31 (4.73)	0.487
High fat & sweet	1.13 (0.92)	1.41 (0.89)	1.35 (0.66)	0.645
Low fat & savoury	2.32 (1.33)	3.11 (2.18)	3.05 (1.23)	0.386
High fat & savoury	7.21 (5.46)	7.17 (3.55)	6.77 (2.62)	0.951
Fat	0.80 (1.35)	0.83 (0.9)	0.85 (0.70)	0.994

Results are presented as means (standard deviations); Statistical difference threshold set at p<0.05; SIT: Sitting condition; LPA: Low-intensity Physical Activity condition; MPA: Moderate-intensity Physical Activity condition

Table 3 Food preferences following conditions

Food categories	SIT	LPA	MPA	p-values
Low fat & sweet (g)	208 (149)	236 (160)	295 (198)	0.040
High fat & sweet (g)	67 (154)	34 (46)	50 (72)	0.524
Low fat & savoury (g)	162 (113)	159 (135)	200 (125)	0.207
High fat & savoury(g)	104 (107)	112 (104)	119 (101)	0.533
Fat (g)	41 (46)	59 (68)	57 (70)	0.293

Results are presented as means (standard deviations); g: gram; Statistical difference threshold set at p<0.05; SIT: sitting condition; LPA: Low-intensity Phycical Activity condition; MPA: Moderate-intensity Phycical Activity condition

Discussion

Identifying strategies to reduce sedentariness is essential, hence the interest in active desks. It is also important to assess the overall response and monitor impacts on behaviors like nutrition. The current study examined for the first time in the literature the impact of using cycling desks performed at light and moderate intensities compared to a conventional seat desk during academic tasks on energy intake (total and macronutrients) and food preferences, both accessed by visual attention (i.e., eye-tracking) and actual energy intake from five food categories of interest. Our results showed no difference in energy and macronutrient intakes between the conditions. Total fixation times of food categories were similar between conditions. However, actual intakes in grams were different for the LFSW food category, with cycling desks at moderate intensity having tendency for higher intakes compared to conventional seated position attributable largely to soft drink consumption.

Our study is the first to assess low and moderate intensity using cycling desks on food intake. The energy intake did not differ between conditions. However, LPA had a reduced energy intake compared to SIT (-20%) and MPA (-17%), which did not reach statistical significance but deserved to be mentioned. In fact, LPA has the potential to increase energy expenditure and reduce intake compare to SIT, contributing to a negative energy balance. For MPA, measurements of energy expenditure are required to better understand if the energy balance is more negative between LPA and MPA.

An average decrease for LPA was observed for all macronutrient and micronutrient intakes when compared to SIT (Carbohydrates: -20%; Lipids: -21%; Proteins: -23%; Fibers: -23% and Sodium: -17%) and MPA (Carbohydrates: -18%, Lipids: -20%, Proteins: -5%, Fibers: -14%, and Sodium: -16%). Our findings differ from those of Thivel et al. (2020), who observed a 510 kJ increase using a similar setup of cycling desks at light intensity alongside a cognitive task measured with an ad-libitum buffet. Their increase in energy intake was due to carbohydrate consumption between the cycling and the seated with cognitive task condition. Our study suggests that even LPA may offer potential energy intake benefits and this, despite the fact that higher intensities are known for their anorexigenic effect (Beaulieu et al. (2020). Our sample predominantly comprised individuals within a normal body mass index range with a mean value of 22.0 (3.6) kg/m^2. Considering that individuals living with excess body weight improve body weight management when using active workstations (Josaphat et al., 2019), it would be valuable to expand this research to this population. With the overweight and obesity prevalence having risen to 30% among students in the US (Centers for Disease Control and Prevention, 2019), this context makes our findings especially relevant.

In the current study, LFSW category was significantly different between the conditions. The difference was mostly due to increased preference for LFSW foods following the MPA condition (SIT vs. MPA; p=0.053). The sweet drink consumption (orange juice, Coca-Cola, and Sprite soft drinks) was part of the LFSW category and could explain the result. While the participants were not allowed to drink any fluids during the cycling desk exercises, they might have quenched their thirst when given the opportunity. The average sweet drink consumption was different between conditions, with MPA having a tendancy to be higher than both LPA and SIT. It should be noted that water was also offered at the ad libitum buffet-type meal, but no difference in water consumption was observed between SIT 393 (223) grams, LPA 397(286) grams, and MPA 359 (242) grams condition (p=0.410). These findings align with a recent review by our group that confirmed that sweet taste and preference increase with acute exercise (Gauthier et al., 2020). It is also in accordance with Beaulieu et al. (2020) who report that low fat food was preferred after exercise. Such findings suggest the potential role of varying exercise intensities in influencing dietary choices. Considering our results and the accessibility of processed and fast food on university campuses (Sogari et al., 2018), there is a potential implication that individuals who use active desks above light intensity should be encouraged to hydrate with healthier options, such as water, as recommended by Canada's Dietary Guidelines (Health Canada, 2019). This is especially relevant considering the growing evidence linking such beverages to the prevalence of obesity (Poorolajal et al., 2020).

Emerging technologies like eye-tracking glasses are beginning to see physical activity and nutrition applications. In our research, using Tobii Glasses 2, the hypothesis was that there would be similarities between food consumption preferences and the visual fixation duration on specific food types. By categorizing food into five groups, our results indicated no similarities between the most frequently viewed category (HFSA) and the most commonly consumed category (LFSW) (See supplemental data, Figures 3 and 4). Also, surprisingly, and despite the conditions, total fixation time on food represented approximately 13% or three minutes of the whole 30 minutes of lunchtime. Before our research, Yasui et al. (2019) identified increased gaze fixations and total gaze fixation duration for more preferred food items. In their study, employing the Tobii eye-tracker, participants were asked to observe three dishes for 10 seconds before choosing and consuming their selected dish. However, their study did not utilize an ad-libitum buffet approach to assess food prediction (Yasui et al., 2019). In another study using eye-tracking glasses with healthy males and done with a buffet-type meal, it was observed that visual fixation towards high-calorie foods was not a decisive indicator for overall food selection

(Wang et al., 2018). Yet, the authors suggest that fixation during food selection might predict savory food choices. The application of eye-tracking technology in this field is innovative (Carter & Luke, 2020), and further research is needed to optimize protocols. Based on our experimentation, factors such as the number of presented foods (i.e., multi-food presentation versus binary presentation of food stimuli), the placement of these foods on the table, and the participants' posture angle may influence the measurements' variability. This influence could arise because certain foods may fall outside the peripheral vision captured by the eye-tracking device, necessitating head movement to capture fixation time. This scenario may mainly be relevant when utilizing eye-tracking glasses in a self-serve buffet protocol.

Strengths and limitations

In this study, we employed a randomized crossover protocol to minimize bias and control individual variability. Adopting an ecological approach mirroring students' daily routines enhance the real-world applicability of our results. Our use of the eye-tracking technology, though in its early integration phase in nutrition studies, holds innovative insights into nutritional behaviors and preferences. However, certain limitations must be acknowledged. The small sample size, typical for exploratory research, limits the generalizability of our findings and detailed statistical analyses by factors like sex, body mass index, or stress. The absence of indirect calorimetry for estimating energy expenditure is another limitation that should be addressed in future studies to better monitor energy balance.

Conclusion

Cycling desks can be integrated into work settings to reduce sedentary behavior without impacting overall energy intake. Low intensity may be recommended, while moderate intensity leads to a preference for LFSW foods such as sweetened beverages and thus impacts diet quality. Eye-tracking technology, although innovative, revealed inconsistencies in predicting food preferences based only on gaze duration. Moving forward, a comprehensive approach that combines active workstations with dietary insights is essential for understanding health behaviors. Further research is recommended to refine methods and address diverse populations, especially those with body weight concerns.

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Authorships

FD is the lead author who contributed to all stages of research studies in the article. AC contributed to the writing and revision of the article, and VD to its revision and editing. RG co-supervised the lead author during experimentation and also revised the article. MEM is the principal supervisor of the lead author and has reviewed, edited, and handled the administrative aspects of the article.

Declarations of interest none

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