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Original research

Effect of acute exercise and cycling-desk on energy intake and appetite response to mental work: The CORTEX Study

Running title: Cognitive work, appetite and exercise

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Key words. Active workstations; exercise; appetite; energy intake; food reward; cognitive work

Abstract

Background. While mental work has been shown to favor overconsumption, the present study compared the effect of a cognitive task alone, followed by acute exercise, or performed on a cycling-desk, on short-term food intake and appetite in adults.

Methods. Nineteen normal-weight adults randomly completed: resting session(CON);30-minute cognitive task(CT);30-minute cognitive task followed by a 15-minute high-intensity interval exercise bout(CT-EX);30-minute cognitive task performed on a cycling desk(CT-CD). Energy expenditure was estimated (heart rate-workload relationship), energy intake (a*d libitum*) and appetite (visual analog scales) were assessed.

Results. Energy expenditure was higher in CT-EX($p<0.001$) compared with the other conditions and in CT-CD compared with CON and CT($p<0.01$). Energy intake was higher in CON($p<0.05$) and CT-CD compared with CT($p<0.01$). Relative energy intake was higher in CON compared with CT($p<0.05$) and lower in CT-EX compared with CT, CT-CD and CON (all $p<0.001$). AUC desire to eat was higher in CON compared with CT ($p<0.05$) and CT-EX($p<0.01$). AUC prospective food consumption was higher in CON compared with CT-EX($p<0.01$). Overall composite appetite score was not different between conditions.

Conclusion. While cycling desks are recommended to break up sedentary time, the induced increase in energy expenditure might not be enough to significantly reduce overall short-term relative energy intake after mental work.

Introduction

Over the last decades, sedentariness has become a major public health concern, being recognized as one of the main avoidable causes of mortality[1]. This is in part due to the increasing amount of time people spend sitting during the day, engaged in screen activities and cognitive tasks rather than physically-demanding tasks[2]. It has for instance been recently suggested that office workers spend at least 7 hours per day seated at their desk, mostly in front of a screen, which is associated with altered health indicators such as increased waist circumference, body mass index or fat mass[3]. This alarming time devoted to sedentary, cognitively demanding activities not only leads to reduced daily physical activity level and thus energy expenditure, but has also been associated with mental fatigue and overeating[4,5].

In their work, Chaput & Tremblay showed that a 45-minute reading task favored increased energy intake (+200 kcal) compared to a control session of quiet sitting, despite an increase of energy expenditure of 3 kcal only[6]. The same group recently obtained similar results in response to both reading and computer tasks in healthy adults[4]. Interestingly, this orexigenic effect of cognitive work has also been positively associated with the mental workload induced by the task, with cognitively more demanding and stressful tasks leading to greater energy[6] or carbohydrate[7] intake.

While physical exercise has been found to lead to a transient anorexigenic effect in healthy adults, recent studies have examined whether introducing an acute bout of exercise after cognitive work could avoid its potential orexigenic impact and positively affect overall energy balance. Although some studies observed decreased food intake when acute exercise precedes mental work[8,9], Lemay and collaborators reported a lower relative energy intake after a cognitive task plus exercise compared to the same cognitive task without exercise, without differences in absolute energy intake[10]. More recently, Neumeier and collaborators asked 40 healthy adults to randomly complete three experimental conditions: i) a control session without a mental task or exercise; ii) 20 minutes of mental work followed by a 15-minute rest period or; iii) the same 20-minute mental work but followed by 15 minutes of interval exercise performed at approximately 80-85% VO_{2max}[11]. Although the authors used an *ad libitum* pizza buffet meal that might have affected their results due to the high level of palatability potentially favoring overconsmuption[12], they observed an increase of approximately 100 kcal at the meal in the mental work condition compared with the control condition, while a mean decrease of 25 kcal was found in response to the cognitive task plus exercise condition[11]. Importantly, the participants who performed the interval exercise after the mental work showed a significant negative energy balance compared to the other conditions, with no difference observed with regards to appetite sensations[11]. While some studies underlined the effect of cognitive work on the consumption of carbohydrate over protein or fat[7], the potential effect of such mental work on the satiety response to a meal remains to be elucidated.

Although public health policies tend to encourage the practice of physical exercise among individuals who spend most of their day sitting, in front of screens and engaged in demanding cognitive tasks, recent results suggest that worksite interventions are difficult to conduct, with high dropout and low compliance rates[3,13]. Alternatives such as active-desks have been developed to encourage human motion and break sedentariness while working[15, 16]. While most of the studies conducted so far investigated the effects of such active workstations on total physical activity and sedentary time[15, 16] as well as cognitive performance[17] among others; it remains unknown whether they can also affect energy intake and appetite control. This issue is of particular relevance if one wants to claim that they can help the management of body weight.

In that context, the aim of the present study was to compare the effect of a cognitive task performed while seated, while using a cycling desk or followed by acute exercise, on appetite control (food intake and subjective appetite) among healthy adults.

Methods

Population

Nineteen apparently healthy normal-weight young adults (21.2± 0.5 years; 10 men and 9 women) were recruited among university students (Clermont-Auvergne University) to participate in this randomized controlled crossover study. To be included in the study, they had to be free of any illnesses or medications that could interfere with the study outcomes (such as muscular or osteo-articular limitations that are not compatible with exercise; heart disease, anxiety medication or eating disorders). The participants also had to self-report a moderate physical activity level, i.e., being engaged in regular physical activity between 150 and 240 minutes per week (thus being above the international recommendations for physical activity), including intensive activities, as assessed using the International Physical Activity Questionnaire (IPAQ). The participants also had to be habitual breakfast consumers. This study was conducted according to the guidelines laid down in the Declaration of Helsinki. Written informed consent was obtained from all participants as requested by the local Research Ethics Committee (University Hospital Human Protection Committee; ref CPP Sud Est VI).

Experimental design

After a medical examination conducted by a physician to confirm the ability of each candidate to perform the whole protocol, anthropometric measurements, body composition (bio-impedance; BIA), aerobic capacity (VO_2submax) and food preferences were assessed. Cognitive eating behavior traits were assessed with the Three-Factor Eating Questionnaire (TFEQ). Then, participants had to complete four experimental sessions on separate occasions (separated by at least 7 days) in a randomized order (block randomized using Stata software): i) a control session without exercise nor cognitive task; participants remained seated on a chair for 30 minutes while relaxing (CON); ii) a 30-minute cognitive task (CT); iii) a 30-minute cognitive task followed by a 15-minute bout of high-intensity interval exercise (HIIE; CT-EX); and iv) a 30-minute cognitive task performed while cycling on a cycling desk (CT-CD). For each session (detailed below), the participants were asked to attend the laboratory at 08:00am after an overnight fast (12 hours). After a standardized breakfast, they were asked to remain sedentary until

11:00am, then were asked to complete one of the above conditions (CON, CT, CT-EX, or CT-CD) until lunch time. Thirty minutes after each condition, they received an *ad libitum* buffet lunch. Energy intake (EI) for the remainder of the day was assessed using self-reported food diaries. Appetite sensations were measured using visual analogue scales (VAS) at regular intervals throughout the sessions (before breakfast, after breakfast, before the experimental condition, after the experimental condition, before lunch, after lunch, 30 minutes and 60 minutes after lunch).

Experimental conditions

Control condition (CON). From 08:00am to 12:00pm, the participants remained sedentary, restricted from any physical exercise. They had access to books and magazines as well as to movies (none of the proposed activities required intensive cognitive work nor included any food cues). From 11:00am to 11:30am they were particularly asked to remain seated without any intensive cognitive or intellectually demanding task (music and entertaining magazines were available).

Cognitive task alone (CT). This session was similar to CON except that the participants performed a 30-minute cognitive task between 11:00am and 11:30am. The task consisted of reading a scientific publication of 8 to 10 pages and to provide an abstract of exactly 250 words based on this publication. To ensure an intensive cognitive task, the publication was chosen by the investigators (who previously read and evaluated the difficulty of the publication) so that the topic addressed was not familiar to the participants. Importantly, the publication chosen was different for each participant from one session to another and the order was randomly allocated.

Cognitive task and exercise (CT-EX). This session was similar to CT except that the participants were asked to perform a 15-minute bout of HIIE on a cycle ergometer after the cognitive task. The HIIE consisted of five 2-minute work intervals performed at 80-85% of estimated VO_{2max} interspersed by 1-minute intervals set at 50% of estimated VO_{2max}. The intensity of the exercise was individually controlled and based on the VO_2submax test previously performed, using both the mechanical workload (in Watts) imposed on the cycle ergometer and the corresponding heart rate (as a double indicator of the targeted intensity).

Cognitive task and cycling desk (CT-CD). This session was similar to CT except that the participants were asked to continuously cycle on a cycling desk (ActivDesk Inc, Paris, France). While the number of revolutions per minutes was not imposed, nor was a specific intensity/workload, the participants were asked to cycle comfortably and their heart rate was continuously recorded.

Anthropometric measurements and body composition assessment

A digital scale was used to measure body mass to the nearest 0.1 kg, and barefoot standing height was assessed to the nearest 0.1 cm by using a wall-mounted stadiometer. Body mass index (BMI) was calculated as body mass (kg) divided by height squared (m^2). Body composition was assessed on the same occasion using BIA (Tanita MC 780). This model has been validated in young adults of various physical activity levels[18].

Submaximal aerobic capacity

Aerobic capacity was assessed during a submaximal graded cycling test performed at least one week before the experimental sessions (during a preliminary visit). The test was composed of 4 stages of 4 minutes, starting at 30 W with an increment of 15 W each stage. An electromagnetically-braked cycle ergometer (Ergoline, Bitz, Germany) was used to perform the test. VO_2 and VCO_2 were measured breath-by-breath through a mask connected to O_2 and CO_2 analysers (Oxycon Pro-Delta, Jaeger, Hoechberg, Germany). Calibration of gas analysers was performed with commercial gases of known concentration prior to each test. Ventilatory parameters were averaged every 30 seconds. Electrocardiography was also used for the duration of the tests. This test, performed under the supervision of an accredited medical doctor, aimed to establish the individual relationship between heart rate and VO_2, and workload (W) and VO_2 in order to estimate the energy expenditure (EE) during each experimental session.[19]

Energy intake

On each experimental day, both males and females received a standardized breakfast of 500 kcal. The *ad libitum* lunch test meal was identical across the four experimental conditions and was composed according to the participants' overall food preferences and consisted of turkey, pasta, green beans, yogurt, stewed apples, butter, bread and white sugar. The content of the buffets was determined based on the participants' food preferences questionnaire completed during the inclusion visit. Top rated as well as disliked items and items liked but not usually consumed were excluded to avoid over-, under- and occasional consumption. Food items that respected these criteria across our sample were then selected to reduce the potential bias linked with different buffet meals. The participants has 45 minutes to eat and were asked to eat until they felt comfortably satisfied. Relative energy intake (REI) was calculated by subtracting the amount of energy expended during the tasks (CON, CT, CT-CD and CT-EX) from the energy ingested at the *ad libitum* buffet meal (REI = EI – EE). Participants had free access to water throughout the duration of the experimental sessions. The participants were then asked to self-report their intake for the rest of the experimental day (until going to bed) assisted by the SUVIMAX method that consists of an instruction manual for coding food portions, which included validated photographs of more than 250 foods represented in three different portion sizes. The self-reported diaries were analyzed by an experienced dietitian. Absolute and relative energy intake and the proportion of the total energy intake derived from fat, carbohydrate and protein were calculated using the Nutrilog software (Nutrilog Inc., Marans, France).

Subjective appetite sensations

At regular intervals throughout the experimental sessions (before and after breakfast, before and after CON, CT, CT-CD or CT-EX, and before, immediately after, and 30 minutes and 60 minutes after the test meal), participants were asked to rate their hunger, fullness, desire to eat (DTE) and prospective food consumption (PFC) using 150-mm VAS. A composite appetite score to represent the overall motivation to eat was calculated as: (Hunger + PFC + DTE + (100-Fullness))/4. Area under the curve (AUC) was calculated based on the trapezoid method.

The reliability of appetite VAS has previously been reported. The satiety quotients (SQ) for hunger, fullness, PFC, DTE and composite appetite score - as indicators of the satiating efficiency of food - were calculated on the lunch meal as follows[20]:

*Satiety quotient (mm/kcal) = [(pre-meal rating) – (mean 60-minute post-meal rating)) / energy content of the meal (kcal)]*100.*

Statistical analysis

The sample size was determined according to recommended procedures (CONSORT 2010 statement and Cohen's recommendations for effect sizes). With 19 subjects by condition, an effect-size around 1 can be highlighted for a two-sided type I error at 0.008 (correction due to multiple comparisons), a statistical power greater than 85% and an intra-class correlation coefficient of 0.5 to take into account between and within participant variability. As no difference between males and females were obtained, the data of the whole sample were pooled and analyzed together.

Statistical analyses were performed using Stata software, Version 15 (StataCorp, College Station, TX, US). Continuous data were expressed as mean and standard deviation and the assumption of normality was assessed using the Shapiro-Wilk test. Outcomes (energy intake, energy expenditure, appetite sensations, satiety quotients) were analyzed using random-effects models for repeated data to compare conditions effect (i) considering time, condition and time x condition interaction as fixed effects, and (ii) taking into account between and within participant variability (subject as random-effect). The normality of residuals from these models was studied as aforementioned. Effect sizes were calculated and interpreted as small (ES: 0.2), medium (ES: 0.5) and large (ES: 0.8, "grossly perceptible and therefore large"). When appropriate, a logarithmic transformation was applied to access the normality of dependent variables. A Sidak's type I error correction was applied to perform multiple comparisons.

Results

The mean body mass of the participants was 67.3 ± 7.5 kg, with a BMI of 22.5 ± 2.2 kg/m^2, percentage of body fat of 19.5 ± 5.7 % and fat-free mass of 54.5 ± 8.2 kg.

Energy expenditure was significantly higher in CT-EX (387 ± 147 kcal; p<0.001) compared with the three other conditions and significantly higher in CT-CD (225 ± 68 kcal; p<0.01) compared with CON (178 ± 59 kcal) and CT (173 ± 50 kcal).

As detailed in Table 1, absolute energy intake was significantly higher in CON and CT-CD compared with CT (p<0.05; ES: 0.49 [0.04 – 0.94] and p<0.01; ES: 0.55 [0.10 – 1.00], respectively) with no difference between CT-EX and the other three conditions. There was no difference in self-reported energy intake over the rest of the day between conditions. While none of the macronutrient distributions differed between conditions, the absolute intake of carbohydrate was significantly higher in CON and CT-CD compared with CT (p<0.05; ES: 0.46 [0.01 – 0.91] and p<0.01; ES: 0.59 [0.14 – 1.04], respectively). Relative energy intake was significantly higher in CON compared with CT (p<0.05; ES: 0.47 [0.02 – 0.92]) and significantly lower in CT-EX compared with CT (p<0.001; ES: -0.90 [-1.35 – -0.45]), CT-CD (p<0.001; ES: 1.21 [0.76 – 1.66]) and CON (p<0.001; ES: 1.36 [0.91 – 1.81]).

According to Table 2, none of the fasting and pre-lunch appetite sensations was significantly different between conditions. AUC for DTE was significantly higher in CON (20726 ± 9595 mm*min) compared with CT (18402 ± 9388 mm*min; p<0.05; ES: 0.09 [-0.36 – 0.54] and CT-EX (11607 ± 4809 mm*min; p<0.01; ES: 0.07 [-0.38 – 0.52]. AUC for PFC was significantly higher in CON (17877 ± 9061 mm*min) compared with CT-EX (10055 ± 5709 mm*min; p<0.01; ES: 0.62 [0.17 – 1.07]. There were no differences in SQs between conditions. None of the fasting, pre-lunch, AUC and SQ for the composite appetite score were different between conditions.

Discussion

While it has been shown that most of the population spends more than 7 hours a day seated and involved in cognitive tasks[2], it has also been suggested that this may not only lead to reductions in physical activity and energy expenditure, but also to increases in energy intake. Active breaks and active workstations have been proposed to reduce this sedentary time and limit the decrease in physical activity level, but it remains unknown whether such workstations can also reduce the overeating induced by mental work.

While our results did not show any overeating in response to a 30-minute cognitive task compared to control in healthy young adults, they highlight that HIIE cycling after a cognitive task, but not the use of a cycling-desk during the task, was able to promote lower relative energy intake. Interestingly, only the acute bout of HIIE performed after the 30-minute cognitive task was able to reduce AUC prospective food consumption and desire to eat compared with the control condition.

According to the present results, a 30-minute cognitive task (CT condition) led to a reduction in absolute energy intake at the following meal compared with a control condition (without mental work), which is contradictory to some previous findings[4-6, 7, 11]. In their work, Chaput & Tremblay showed a 200-kcal increase in energy intake in response to a 45-minute reading task in a similar population[6], later providing similar results after both reading and computer tasks[4]. Although the mental stress induced by a cognitive task has been found to be positively associated with increased energy[6] and carbohydrate[7] intake, Ding et al. recently showed that working on a computer while consuming food significantly increased stress but had no influence on overall energy intake compared to a control condition in healthy adults[21]. While the present results contradictorily demonstrate a decrease in energy intake, mainly due to a reduction in carbohydrate intake, in response to a 30-minute cognitive task compared with the control condition, this could be explained by the profile of our participants. Indeed, although we voluntarily selected a task that was supposed to require a high level of concentration and that was timed in order to create some mental constraint and stress, our sample was composed of university students (Master's degree), who are used to this type of cognitive workload, especially at the time of data collection which was close to their semester exams. Further studies should be conducted in other samples to examine whether the level of habitual cognitive workload can affect the food response to such tasks. Interestingly, while Pérusee-Lachance et al. found greater energy intake in response to a mental task in healthy young females and observed the opposite among males[22]; we did not find any sex differences in the present study.

Based on this previously reported post-mental work overconsumption and following the public health recommendations to increase physical activity, particularly among office workers, some studies investigated whether implementing exercise before or after a bout of cognitive work could help with the control of appetite and energy intake. Some studies showed a decrease in food intake when an acute bout of exercise was performed immediately before mentally-demanding work[8, 9]. Recently, Neumeier and colleagues randomly asked male and female university students to either perform a mental task alone, followed by an *ad libitum* meal, or to perform 15 minutes of HIIE (80-85% heart rate max) in-between the mental task and the meal[11]. Although they did not find differences in terms of appetite sensations, they observed a 100-kcal mean increase in energy intake in response to the mental task alone while energy intake was only slightly reduced in the mental task + exercise condition (by 25 kcal compared to the control condition), significantly reducing relative energy intake[11]. This lower overall energy balance when exercise is performed between cognitive work and a meal has been also observed by Lemay et al. (2014) among 15- to 20-year-old male students, despite unchanged absolute energy intake, which corroborates the current results.

Since implementing traditional physical exercise remains difficult between office hours and meals[13], new alternatives such as active workstations have been developed to break sedentary time and increase physical activity level. While their effects on energy expenditure have been studied, it remained unknown whether they could also help control appetite and energy intake after mentally demanding cognitive tasks. Although we did not observe the usually-described overconsumption in response to our cognitive task relative to control, the use of a cycling-desk during the task led to significantly higher energy intake compared to the cognitive task alone. Furthermore, the use of a cycling-desk did not lead to lower relative energy intake compared to the other conditions despite the induced energy expenditure, except compared with the exercise session (CT-EX). The CT-EX session was indeed the only condition that induced a significantly lower relative energy intake and reduced AUC desire to eat and prospective food consumption.

These results must be interpreted in light of some limitations. First, the level of mental challenge induced by our cognitive task may not have been high enough to elicit a stress response to affect energy intake and subjective appetite in this young and healthy university student sample. A measure of stress level (i.e. salivary cortisol or subjective ratings) would have provided evidence for this. Moreover, our sample was composed of moderately active healthy individuals, thus with a physical activity level above the international recommendations (>150 minutes per week of at least moderate-intensity exercise). Further studies should be conducted among inactive individuals whose appetite control has been shown to be altered and could be more at risk of overeating in response to such cognitive tasks.[23] It would have also been of interest to directly measure the participants' energy expenditure during the conditions using indirect calorimeter, which was not possible for practical reasons. While self-reported energy intake was assessed for the rest of the experimental days, it would have been better to evaluate the participants' intake for the following 24- to 48-hours using more objective methods (such as the distribution of prepared buffet meals and the collection of the uneaten items). Similarly, although participants had free access to water during the experimental sessions, this should have been precisely assessed. Despite these limitations, our work also has some strengths, such as the presence of both a control condition without any exercise or cognitive task and a condition with a cognitive task alone, which previous work lacked. The use of an objective evaluation of energy intake using an *ad libitum* buffet meal whose composition avoided any bias linked with the palatability or individual preferences of the food items proposed among our participants is also a strength of this work.

To conclude, while the present results need to be further examined and confirmed by other studies, they suggest that the use of a cycling-desk while performing mental work does not favor reduced relative energy intake in healthy young adults. While such active workstations are recommended to break sedentary time in people spending hours working seated at their desk, the induced increase in energy expenditure might not be enough to significantly reduce overall short-term relative energy intake.

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References

[1] Dempsey PC, Strain T, Khaw KT, Wareham NJ, Brage S, Wijndaele K. Prospective Associations of Accelerometer-Measured Physical Activity and Sedentary Time With Incident Cardiovascular Disease, Cancer, and All-Cause Mortality. Circulation. 2020 Mar 31;141(13):1113-1115

[2] Saidj M., Menai M, Charreire H, Weber C, Enaux C, Aadahl M. et al. Descriptive study of sedentary behaviours in 35,444 French working adults: cross-sectional findings from the ACTI-Cites study. BMC Public Health (2015) 15: 379.

[3] Genin PM, Dessenne P, Finaud J, Pereira B, Dutheil F, Thivel D, et al. Effect of work-imposed sedentary time on overall health profile in active *vs* inactive tertiary employees. Frontiers in Public Health (2018) 2018 Oct 1;6:279. doi: 10.3389/fpubh.2018.00279. eCollection 2018.

[4] Chaput JP, Drapeau V, Poirier P, Teasdale N, Tremblay A. Glycemic instability and spontaneous energy intake: Association with knowledge-based work. Psychosom Med. 2008; 70(7):797–804. [PubMed: 18725427]

[5] Chaput JP, Klingenberg L, Astrup A, Sjodin AM. Modern sedentary activities promote overconsumption of food in our current obesogenic environment. Obes Rev. 2011; 12(5):e12–20. [PubMed: 20576006]

[6] Chaput JP, Tremblay A. Acute effects of knowledge-based work on feeding behavior and energy intake. Physiol Behav. 2007; 90(1):66–72. [PubMed: 17023010]

[6] McCann B, Warnick G, Knopp R. Changes in plasma lipids and dietary intake accompanying shifts in perceived workload and stress. Psychosom Med. 1990; 52(1):97–108. [PubMed: 2305026

[7] Hitze B, Hubold C, van Dyken R, et al. How the selfish brain organizes its supply and demand. Front Neuroenergetics. 2010; 2:7. [PubMed: 20616886]

[8] Horsch A, Wobmann M, Kriemler S, et al. Impact of physical activity on energy balance, food intake and choice in normal weight and obese children in the setting of acute social stress: A randomized controlled trial. BMC Pediatrics. 2015; 15(1):326

[9] Oh H, Taylor AH. Brisk walking reduces ad libitum snacking in regular chocolate eaters during a workplace simulation. Appetite. 2012; 58(1):387–92.

[10] Lemay V, Drapeau V, Tremblay A, Mathieu ME. Exercise and negative energy balance in males who perform mental work. Pediatr Obes. 2014; 9(4):300–9
[11] Neumeier WH, Goodner E, Biasini F, Dhurandhar EJ, Menear KS, Turan B, Hunter GR. Exercise Following Mental Work Prevented Overeating. Med Sci Sports Exerc. 2016; 48(9): 1803–1809
[12] Thivel D, Duché P, Morio B. Discussion of "overweight and obese boys reduce food intake in response to a glucose drink but fail to increase intake in response to exercise of short duration". Appl Physiol Nutr Metab. 2012 Oct; 37(5):1014-5.
[13] Genin PM, Pereira B, Thivel D, Duclos M. Employees' adherence to worksite physical activity programs: Profiles of compliers versus non-compliers. Work. 2018;60(3):507-510.
[14] Josaphat KJ, Kugathasan TA, E R Reid R, Begon M, Léger PM, Labonté-Lemoyne E, Sénécal S, Arvisais D, Mathieu ME. Use of Active Workstations in Individuals with Overweight or Obesity: A Systematic Review. Obesity (Silver Spring). 2019 Mar;27(3):362-379.
[16] Torbeyns T, Bailey S, Bos I, Meeusen R. Active workstations to fight sedentary behaviour. Sports Med. 2014 Sep;44(9):1261-73.
[17] Schwartz B, Kapellusch JM, Baca A, Wessner B. Medium-term effects of a two-desk sit/stand workstation on cognitive performance and workload for healthy people performing sedentary work: a secondary analysis of a randomised controlled trial. Ergonomics. 2019 Jun;62(6):794-810.
[18] Verney J, Schwartz C, Amiche S, Pereira B, Thivel D. Comparisons of a Multi-Frequency Bioelectrical Impedance Analysis to the Dual-Energy X-Ray Absorptiometry Scan in Healthy Young Adults Depending on their Physical Activity Level. J Hum Kinet. 2015 Oct 14;47:73-80
[19] Rowland TW. Developmental Exercise physiology. Human Kinetics ed. Champaign, IL1996.
[20] Drapeau V, King N, Hetherington M, Doucet E, Blundell J, Tremblay A. Appetite sensations and satiety quotient: predictors of energy intake and weight loss. Appetite. 2007;48(2):159-66.
[21] Ding F, Hamid N, Shepherd D and Kantono K. How is Satiety Affected When Consuming Food While Working on A Computer? Nutrients. 2019, 11, 1545; doi:10.3390/nu11071545
[22] Pérusse-Lachance E, Brassard P, Chaput JP, Drapeau V, Teasdale N, Sénécal C, Tremblay A. Sex Differences in the Effects of Mental Work and Moderate-Intensity Physical Activity on Energy Intake in Young Adults. ISRN Nutr. 2013; 2013: 723250.
[23] Beaulieu K, Hopkins M, Blundell J, Finlayson G. Homeostatic and non-homeostatic appetite control along the spectrum of physical activity levels: An updated perspective. Physiol Behav. 2018 ; 192:23-29.

Tables

Table 1. Absolute and relative *ad libitum* energy and macronutrient intake.

	CT		CT-CD		CT-EX		CON		
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*p-value*
EI (kcal)	526	195	648**	284	559	222	633*	218	0.05
Protein (g)	23	12	27	14	23	9	28	10	0.17
Fat (g)	13	7	16	9	13	9	15	9	0.16
CHO (g)	80	29	100**	45	88	37	96*	31	0.05
Protein (%)	16.8	5.0	16.5	5.0	17.0	3.7	17.7	3.0	0.80
Fat (%)	21.5	9.0	21.0	8.3	19.7	11.0	21.1	8.9	0.87
CHO (%)	61.7	10.2	62.5	8.7	63.2	9.1	61.3	7.7	0.86
REI (kcal)	352	191	421$^{\$\$\$}$	273	140***	196	454$^{*,\$\$\$}$	215	0.00

CT : Cognitive Task; CT-CD : Cognitive Task + Cycling Desk ; CT-EX : Cognitive Task + Exercise; CON : Control; SD : Standard Deviation ; EI : Energy Intake ; CHO : Carbohydrates ; REI : Relative Energy Intake ; *p<0.05 vs. CT; **p<0.01 vs. CT ; ***p<0.001 vs. CT ; $$$p<0.001 vs. CT-EX.

Table 2. Fasting, pre-lunch, total area under the curve and satiety quotients for each appetite rating.

	CT		CT-CD		CT-EX		CON		
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*p-value*
pre-BF Hunger	70	40	85	34	71	42	62	39	0.21
pre-BF Fullness	34	31	39	32	44	35	52$^{\#}$	42	0.18
pre-BF DTE	90	37	93	29	74	45	79	41	0.78
pre-BF PFC	87	36	88	35	76	52	78	43	0.98
pre-BF Composite	80	32	80	30	67	37	66	39	0.79
pre-lunch Hunger	86	37	93	30	82	34	93	38	0.72
pre-lunch Fullness	36	37	35	26	37	26	32	32	0.94
pre-lunch DTE	98	34	97	32	89	26	104	29	0.57
pre-lunch PFC	99	34	107	33	91	36	98	34	0.70
pre-lunch Composite	87	28	91	28	78	27	92	28	0.55
AUC Hunger	13598	7797	13270	7562	8959	5075	15515	7939	0.14
AUC Fullness	27647	11936	32333	13433	35436	9550	30440	10660	0.32
AUC DTE	18402	9388	18490	11425	11607	4809	20726$^{*,\$\$}$	9595	0.03
AUC PFC	15617	8724	15186	8608	10055	5709	17877$^{\$\$}$	9061	0.04
AUC Composite	13433	7528	11826	8858	8136	5584	14517	8678	0.18
SQ Hunger	13.5	8.9	12.3	6.0	14.1	5.8	13.6	8.9	0.93
SQ Fullness	-10.3	13.3	-13.6	7.8	-17.8	11.4	-13.4	9.9	0.42
SQ DTE	14.6	9.2	12.3	6.1	15.3	6.5	13.9	8.15	0.71
SQ PFC	16.8	8.8	15.8	7.0	16.8	6.4	13.2	7.9	0.52
SQ Composite	14.3	8.2	13.8	5.3	16.1	4.9	13.7	7.2	0.75

CT : Cognitive Task; CT-CD : Cognitive Task + Cycling Desk ; CT-EX : Cognitive Task + Exercise; CON : Control; SD : Standard Deviation ; BF : Breakfast ; DTE : Desire to eat ; PFC : Prospective Food Consumption ; SQ : Satiety Quotient; *p<0.05 vs. CT ; $$p<0.01 vs. CT-EX; $$$p<0.001 vs. CT-EX; #p<0.001 vs. CT-CD.

Figures

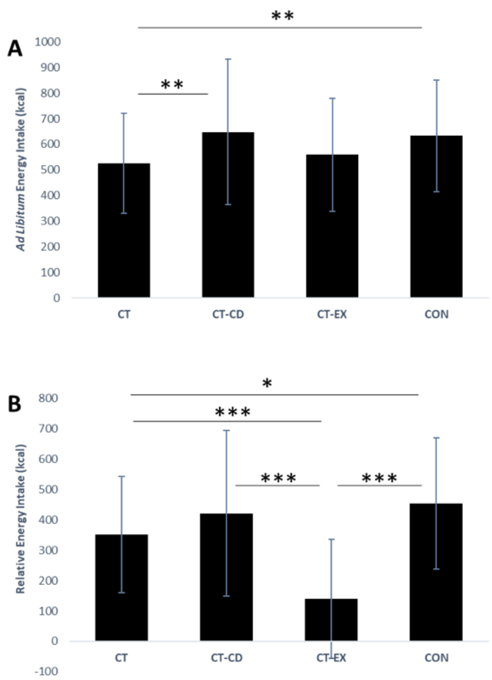

Figure 1. Absolute (A) and relative (B) energy intake in the control (CON), Cognitive Task condition (CT), Cognitive Task and cycling desk condition (CT-CD) and Cognitive Task and Exercise condition (CT-EX). Values are mean ± SD; *p<0.05; **p<0.01; ***p<0.001.

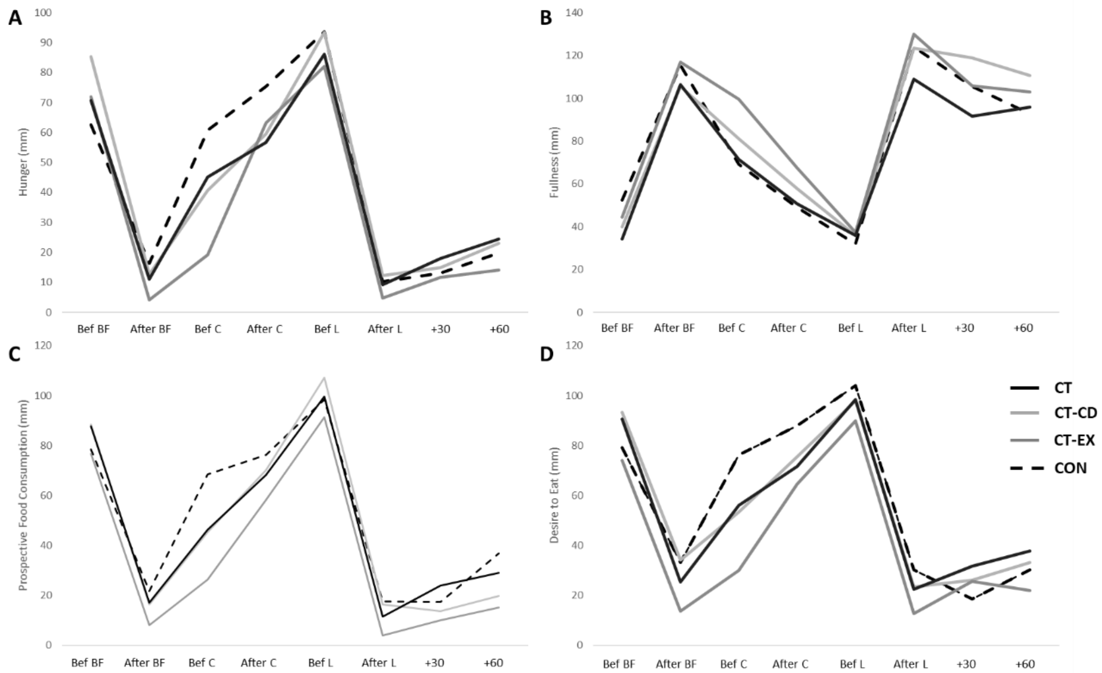

Figure 2. Hunger (A), Fullness (B), Prospective Food Consumption (C) and Desire to Eat (D) sensations throughout the three experimental sessions. **Bef BF: Before Breakfast; After BF: After Breakfast; Bef C: Before condition; After C: After Condition; Bef L: Before Lunch; After L: After Lunch; CT: Cognitive Task condition; CT-CD: Cognitive Task + Cycling Desk condition; CT-EX: Cognitive Task + Exercise condition; CON: Control condition; BF: breakfast, VAS: Visual Analogue Scale.**