Current Issues in Sport Science
ISSN: 2414-6641
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Universität Bern
Suiza

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Current Issues in Sport Science, vol. 7, 2022
Universität Bern, Suiza
Disponible en: https://www.redalyc.org/articulo.oa?id=677872669003
DOI: https://doi.org/10.36950/2022ciss001

Public Health

Physical activity in short study breaks: Short-term effects on cognition and potential for implementation in students' everyday life

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Current Issues in Sport Science, vol. 7, 2022

Universität Bern, Suiza

DOI: https://doi.org/10.36950/2022ciss001

Redalyc: https://www.redalyc.org/articulo.oa?id=677872669003

Abstract: Prolonged bouts of sitting while studying are a common behavior in college students. To prevent sitting-induced decline in cognition, restorative breaks are necessary. The activity during the breaks should be beneficial for cognitive abilities and should show characteristics favoring the implementation of the activity in students' everyday life. Therefore, the aim of the present study was to investigate the effect of a short physical activity intervention (running) on cognition and behaviorally important variables.

Using a within-subject crossover design with randomized starting order, 15 students of sport science completed a ten-minute running bout and a sitting bout with equal duration (washout: one week). The basal cognitive domain of visual attention was assessed immediately post-intervention using a modified trail making test. Information on perceived efficacy, affective states (pre, post, and at follow-up 30 minutes after the intervention), and satisfaction with the intervention (at follow-up) was collected.

Visual attention showed a significant period-by-sequence group interaction, . = .028, part. $\eta^2 = 0.32$, with higher attention immediately after the physical activity bout compared to the sitting bout. Perceived attention, . = .048, part. $\eta^2 = 0.19$, and perceived arousal, . = .007, part. $\eta^2 = 0.30$, showed significantly stronger pre-post increases after the physical activity bout compared to the sitting bout, which were not evident pre-follow-up, . > .596. No significantly different changes in affective valence were found between conditions, . = .669, part. $\eta^2 = 0.03$.

The findings suggest a short-term positive effect of the physical activity bout on cognition, revealing the potential of using physical activity bouts intentionally prior to cognitively challenging study tasks in the population of students of sport science. Furthermore, the physical activity bout in the present form (running indoors) showed limited potential for an implementation in students' everyday life since the behaviorally important variables were similar at follow-up.

Keywords: executive function, exercise, restoration, sedentary, Theory of Planned Behavior.

Introduction

Traditionally, most theoretical knowledge at university is taught in a sitting posture resulting in a large amount of time spent sitting in college students. A recent study reports an average of more than nine sitting hours per day both in female and male undergraduate students (Juren et al., 2020). Accelerometer-based assessments yield similar results with a mean of 10.7 hours per weekday (Felez-Nobrega et al., 2018). Similarly, college students of sport science, who are supposed to be multiplicators of physical activity (PA) behavior (i.e., non-sitting behavior), spend a large amount of time sitting (Öncen & Tanyeri, 2020). An increased PA behavior in college students should be promoted given multiple health benefits connected with PA (Petruzzello & Box, 2020). However, the large amount of time spent sitting in college students does not facilitate a physically active behavior throughout the day. Physical activity conducted aside of the study routine (e.g., after the study day or in breaks) may attenuate adverse associations of health and sitting time (Ekelund et al., 2016).

Sitting behavior in the long-term is associated with detrimental effects later in life (see Petruzzello and Box, 2020, for a narrative review). At the same time, prolonged bouts of sitting (i.e., more than one hour) might result in acute negative consequences on cognitive abilities (Baker et al., 2018; Mullane et al., 2017; Triglav et al., 2019). Specifically, the average number of attention task errors increased around 15% after four hours of working on a computer in a sitting position translating to a cognitive decline from pre-sitting position to post-sitting position (Triglav et al., 2019). Baker et al. (2018) reported a decline in problem solving capacity and an increase in perceived discomfort after two hours of sitting in a pre-post study design. Using a crossover study design with randomized starting order, average overall accuracy was 8% lower after an equally lasting bout of sitting compared to a six-hour bout of standing (Mullane et al., 2017).

The university context may favor the negative consequences of prolonged sitting on cognitive abilities, since study courses regularly last longer than one hour and nearly 30% of sitting bouts in students last longer than one hour (Felez-Nobrega et al., 2018). Therefore, it is important to consider restorative breaks in the everyday life of students.

It is desirable that the selection of the activity in short breaks is based on at least three aspects. Firstly, the activity should be appropriate to be conducted regularly; in this context, both affective and cognitive processes are important to consider. A more pleasurable state (i.e., higher affective valence) during and after the activity is connected with a higher chance to repeat the activity (Williams et al., 2008). As a cognitive variable, higher perceived efficacy is connected with a stronger belief in the activity, which contributes to the maintenance of behavior according to the Reasoned Action Approach (Fishbein & Ajzen, 2010).

Secondly, the activity in the short break should be beneficial for cognitive abilities. Several meta-analyses including both observational and experimental studies showed improved basic cognitive abilities including attentional, working memory, and inhibition domains of cognition after PA bouts (Chang et al., 2012; Hsieh et al., 2021; Janssen et al., 2014). Similarly, when only experimental studies were included in a meta-analysis, positive effects of aerobic PA on time-dependent and accuracy-dependent cognitive tasks were reported (Ludyga et al., 2016). Based on a summary of available evidence, it was suggested that PA bouts with more vigorous intensity showed diminished effects compared to moderate-intense PA bouts (Pontifex et al., 2019). However, the evidence on PA bouts with more vigorous intensity, which increased considerably in the previous years, provides support also for high-intensity interval training with an intensity of approximately 90% of maximal aerobic capacity. A recently published systematic review summarized 23 studies with 13 studies focusing on acute effects of vigorous-intense PA bouts and reported beneficial findings on cognitive abilities (Hsieh et al., 2021).

Thirdly, breaks should be easy to implement in the student's life favoring short breaks. However, the evidence investigating PA bouts with a shorter duration (i.e., ten minutes and below) is still scarce. Kao et al. (2017) reported more pronounced positive effects of a nine-minute vigorous PA bout on inhibitory control compared with a 20-minute moderate-intense bout. The authors did not collect variables related to future behavior. Therefore, it is unknown, if participants are willing to integrate vigorous-intense PA bouts in their everyday life. In a previous study, we found beneficial effects on attention and perceived attention after a ten-minute PA bout compared to a sitting bout, but no beneficial effects on affective valence (Niedermeier et al., 2020). However, this previous study suffered from some limitations including a between groups design, one unsupervised group, and potential weather influences on the PA bout.

Therefore, the primary goal of the present study was to investigate the effect of a ten-minute physical activity intervention (running with vigorous intensity) on cognitive and affective aspects using a crossover design. We hypothesized that the physical activity condition shows more positive cognitive effects in comparison to a sitting control condition, ideally in combination with a perceived efficacy and a more positively valenced affective state. To overcome limitations of our previous study in this context (Niedermeier et al., 2020), we applied a crossover design, both conditions were supervised by one researcher each, the physical activity condition was conducted indoors to minimize weather influences, and we additionally aimed to gain insight in break routines and satisfaction with the interventions.

Methods

Design and procedure

The present study was a follow-up investigation of a study previously published (Niedermeier et al., 2020). In contrast to the previously conducted study, a within-subject crossover design with randomized starting order was selected (Figure 1). All participants completed two interventions at the same time of day with a washout phase of one week between interventions. One intervention contained a PA bout and the other a sitting control condition. Randomization of the starting order was done to minimize familiarization effects (block randomization, block size: two). Participation was on a voluntary basis. Information on the aim of the study and the procedure was given to the participants prior to the study start. All participants were instructed to keep the week schedule including physical activity behavior of week 1 similar to week 2. Ethical approval was received by the Board for Ethical Questions in Science of the University of Innsbruck (#50/2019).

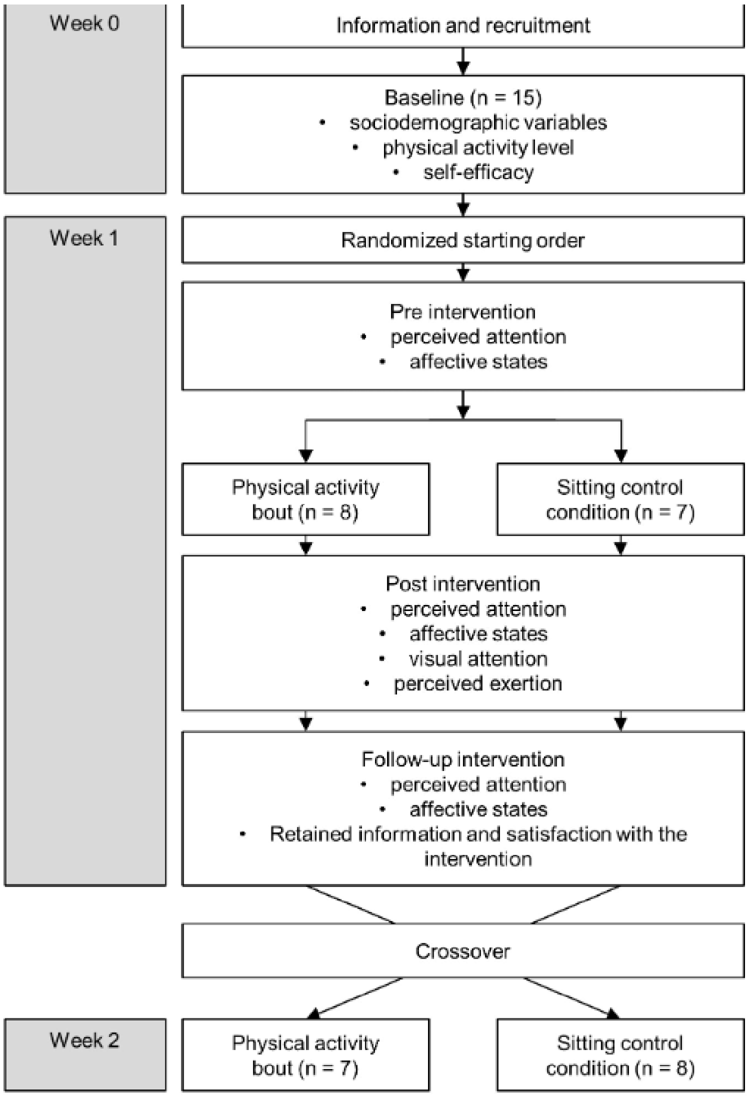

Figure 1

Flow diagram and overview on the study design including measurements. Measurements in week 2 were identical to week 1

Baseline data were collected in week zero. Data referring to the interventions were assessed in week one (test 1) and two (test 2) on three different time points during each of the two study courses: immediately prior to intervention (pre), immediately after intervention (post), and approximately 30 minutes after intervention (follow-up). Time point pre was 42 minutes after the start of the study course and time point follow-up was at the end of the study course. The study course had a total duration of 1.5 hours and started at 1:00 p.m. Visual attention and perceived exertion were assessed once post intervention. Visual attention was assessed only once to avoid unintended improvements due to familiarization (McCaffrey & Westervelt, 1995). Affective states and perceived attention were measured three times per intervention pre, post, and following-up the intervention. Additionally, questions on retained information and satisfaction with the intervention were asked at follow-up.

Participants

All sport science students of a lecture lead by two of the researchers in the summer term 2019 were asked to participate and all (n = 15) students of the lecture participated. Sport students are considered showing a higher-than-average aerobic fitness and relatively high PA level. Exclusion criteria (acute sickness and injuries) were assessed by self-report.

We did not conduct an a priori power analysis for the present study; however, a sensitivity analysis for the present sample was performed for the primary outcome in accordance with Pontifex et al. (2019). Using G*Power 3.1 (University of Düsseldorf, Düsseldorf, Germany; Faul et al., 2007), a minimal effect size of . = 0.78 (Cohens d = 1.56) was revealed with the present sample size of 15 participants (assumptions: alpha = .05, power = .80, group-by-time interaction in a 2 × 2 mixed analysis of variance as the statistical analysis).

Interventions

All students participated in two interventional conditions each lasting ten minutes, a PA bout (running) and a sitting condition. In accordance to our previous study (Niedermeier et al., 2020), a running intensity between "somewhat hard" (13) and "hard" (15) according to the Ratings of Perceived Exertion was instructed (Borg, 1982). The running intensity corresponded to the lower level of vigorous intensity (American College of Sports Medicine, 2018). The PA bout was conducted indoors to minimize weather-induced confounding. All students were instructed to wear sportswear during the PA condition. To avoid a delay prior to the measurements, the students did not take a shower after the PA condition. In the sitting condition, the participants were asked to remain in a sitting position; however, using the bathroom was allowed. Furthermore, reading and talking was allowed. Each of the conditions were supervised by a separate test leader.

Measurements

Baseline data

Using a web-based questionnaire containing 32 questions, socio-demographic data, PA level, and information on study breaks was assessed (completion time: approximately ten minutes). The short form of the International Physical Activity Questionnaire (IPAQ) was used to assess PA level of the past week (http://www.ipaq.ki.se/). The IPAQ allows to estimate energy expenditure in metabolic equivalent minutes (MET min) as a proxy for PA level (http://www.ipaq.ki.se/). Psychometric criteria of the IPAQ include $\rho = .80$ for test-retest reliability and $\rho = .30$ to accelerometer-based measurements for convergent validity (Craig et al., 2003).

Information on study breaks was assessed with a non-standardized questionnaire. The questionnaire included questions on present behavior in study breaks and on barriers to integrate physically active breaks in everyday university life. The questions on behavior in study breaks followed the IPAQ and referred to the last seven days and the same examples for PA with different intensities were provided. Since the behavior during lunch break is expected to be different compared to other breaks, lunch break was excluded from these questions asking for frequency, duration, and specific behavior during study breaks. A five-point Likert scale ranging from "never" to "almost always" was provided for specific behavior during the study breaks.

Visual attention

The primary outcome – visual attention according to the Zahlen-Verbindungs-Test (Oswald, 2016) – was assessed post intervention. The Zahlen-Verbindungs-Test provides information on visual search, scanning, and speed of processing and is similar to part A of the Trail Making Test (Tombaugh, 2004). The group version of the test was used following the instructions of the manual. The instruction includes a short example prior to the test to guarantee full understanding by the participants. Circled numbers printed on four different sheets have to be connected in a numerical sequence (i.e., 1, 2, 3, etc.) as fast as possible using a pencil. The four sheets of paper are provided for 30 seconds each without breaks in between and the average number reached is the primary outcome of the test. Higher visual attention is indicated by higher values of average numbers reached. Test-retest reliability values of . = .80 and convergent validity of . = .60 to other attention/processing speed tests are reported for students (Oswald, 2016). Attention plays a crucial role in a variety of contexts including the university context to retain information (Schellig et al., 2009).

Perceived attention, affective states, and perceived exertion

Perceived attention was rated on a single item question ("Please rate your present attention.") with a visual analog scale ranging from "low" (0) to "high" (100). Dimensional affective states – affective valence and perceived arousal – were assessed using the Feeling Scale (Hardy & Rejeski, 1989) and the Felt Arousal Scale (Svebak & Murgatroyd, 1985). The single-item scales cover the two basic dimensions of the Circumplex model of affect (Russell, 1980). Acceptable convergent validity values are provided for the German version (. = .50 to .73; Maibach et al., 2020). The Ratings of Perceived Exertion was asked for perceived exertion with respect to the intervention time post both interventions (Borg, 1982). The single-item scale ranges from six ("no exertion") to 20 ("maximum exertion"). Reliability values of . > .90 and convergent validity values of . > .80 were reported by Borg (1998).

Retained information and satisfaction with the intervention

Three multiple choice questions containing five to six response options each referring to the content of the study lesson prior to the break were asked to assess the amount of retained information at follow-up. Consecutively, a retained information score was calculated ranging from 0% (all response options incorrect) to 100% (all response options correct). Satisfaction with the intervention was assessed with a mixed approach containing two standardized single-item questions on the probability of recommending the intervention to a friend (Reichheld, 2003), the probability of integrating the intervention in everyday life, and qualitative questions on preferences and adaptations to the interventions done. Response options of the single-item questions were between 0 (low probability) and 10 (high probability). The qualitative questions were asked at the follow-up of the second intervention only.

Statistical analyses

SPSS version 25 (IBM, New York, United States) was used for all statistical analyses. Preliminary analyses on normal distribution (Shapiro-Wilk tests), on homogeneity of variances (Levene-tests), and potential period effects were conducted. We did not test for carry-over effects following Senn (2002). Wherever significant period effects were found (i.e., differences between test 1 and test 2), the data were analyzed according to the Hills-Armitage approach following the recommendations of Senn (2002). The Hills-Armitage approach considers the sequence order (i.e., which group received the PA bout first) and is recommended when period effects (e.g., due to familiarization with the test) are expected (Senn, 2002). When no significant period effects were found, a paired analysis was conducted, i.e., the sequence order was not accounted for (Elbourne et al., 2002). Therefore, the main analysis was different for the outcomes. For the primary outcome visual attention, where significant period effects were expected and present, a 2 × 2 mixed analysis of variance (ANOVA) was done. A significant interaction between the factor sequence group (levels: PA - sitting condition, sitting condition - PA) and period (levels: test 1, test 2) was seen as a different effect of the conditions on visual attention. Additionally, we calculated Pearson's correlation coefficient between test 1 and test 2. For the secondary outcomes perceived attention and affective states, where significant period effects were absent, a 2 × 3 fully repeated measures ANOVA was conducted. Significant interactions between the factor condition (levels: PA, sitting condition) and time (levels: pre, post, follow-up) were regarded as different effects of the conditions. Pre-planned contrasts using time point "pre" as reference category were conducted in case of significant interactions. Mauchly test indicated no significant violation of the assumption sphericity. For the other secondary outcomes, where significant period effects were absent and normality could not be assumed, Wilcoxon test was used to compare between conditions

As an effect size, partial η^2 (part. η^2) was given for all ANOVAs and Rosenthal's . for all Wilcoxon tests. P-values below α = .05 were considered as significant (two-tailed). Unless otherwise stated, data are presented as mean and standard deviation (*SD*).

Results

Baseline characteristics

Mean age of the *n* = 15 participants was 21.6 (*SD*: 3.5) years with 33.3% (n = 5) being female and 66.7% (*n* = 10) being male (Table 1). The participants reported a mean body mass index of 22.3 (*SD*: 2.0) kg/m² and a mean PA level according to the IPAQ of 8597 (*SD*: 4387) MET minutes per week. Not counting lunch breaks, 2.7 (*SD*: 1.4) breaks per day with a mean duration of 26.7 (*SD*: 21.4) minutes were specified.

Table 1
Baseline characteristics by sex

Female (n = 5)		Male (n = 10)		
	Mean	(*SD*)	Mean	(*SD*)
Sociodemographic variables				
Age (years)	19.6	(1.1)	22.6	(3.9)
Body mass index (kg/m²)	21.2	(1.4)	23.8	(1.6)
Physical activity level (MET minutes/week)	8435	(4078)	8679	(4746)
Study breaks				
Frequency (per day)	2.4	(1.7)	2.8	(1.4)
Duration (minutes)	40.0	(25.5)	20.0	(16.7)

Legend: MET minutes/week: metabolic equivalent minutes per week, SD: standard deviation.

Most frequent behaviors during study breaks were light PA, followed by consuming social media, music, or video clips, and drinking (Figure 2). In addition to the categories provided, power napping was mentioned as a frequent study break behavior by 26.7% (n = 4) of the participants. More than half of the sample (57.1% [n = 8, missing data: n = 1]) stated that they nave integrated a physically active break in their everyday university life.

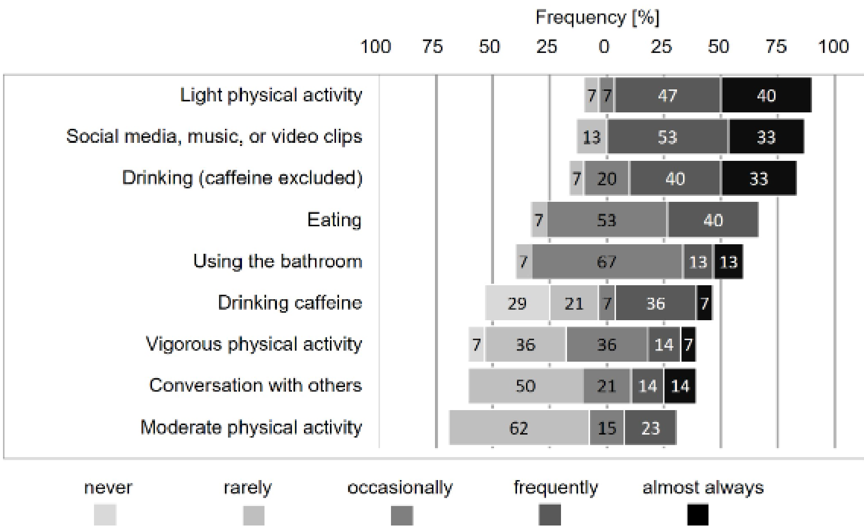

Figure 2
Behavior in study breaks of the last seven days sorted by frequency. Rounding may result in totals greater than 100%

Intervention characteristics

The mean intensity according to the Ratings of Perceived Exertion was 14.5 (*SD*: 1.5) for the PA bout and 6.7 (*SD*: 1.3) for the sitting condition. The total distance covered in the PA bout was between 1,100 and 1,500 meters.

Visual attention

A significant period-by-sequence group interaction was found, .(1, 13) = 6.09, p = .028, part. η^2 = 0.32, indicating a different effect of the conditions on visual attention. The group being physically active prior to the test showed higher visual attention at both test 1 (56.1 [*SD*: 7.4]) and test 2 (62.7 [*SD*: 6.9]) compared to the group receiving the sitting control condition at test 1 (52.0 [*SD*: 6.9]) and at test 2 (62.1 [*SD*: 7.6]; Figure 3). The within-person correlation between test 1 and test 2 was r = .83, . < .001. The main effect of the factor period was significant with a higher value at test 2, F(1, 13) = 80.04, . < .001, part. η^2 = 0.86.

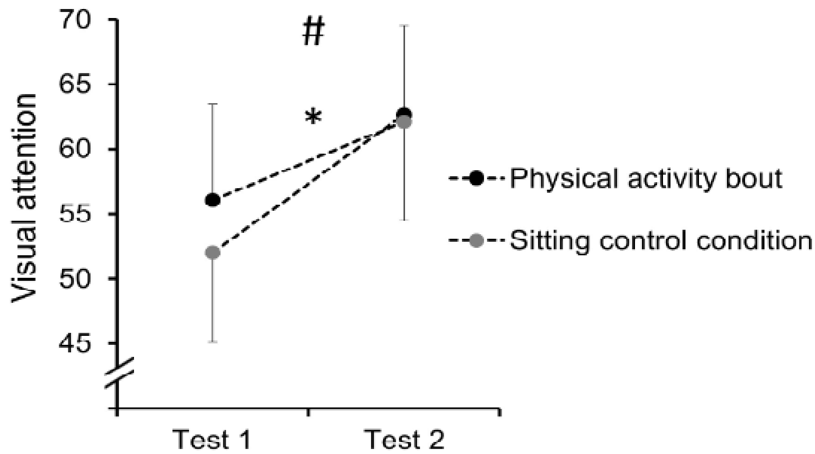

Figure 3
Cognitive domain visual attention according to the performance in the Zahlen-Verbindungs-Test separately for each sequence group
*: significant period-by-sequence group interaction, #: significant period effect.
Dots represent group mean values and error bars indicate standard deviations.

Secondary outcomes

Perceived attention and affective states

Significant condition-by-time interactions were found both for perceived attention, .(2, 28) = 3.39, p = .048, part. η^2 = 0.19, and perceived arousal, F(2, 28) = 6.05, p = .007, part. η^2 = 0.30. Simple contrasts showed a significant pre-post increase in perceived attention, p = .017, and perceived arousal, p = .005 (Figure 4). Pre-follow-up changes were not significantly different between conditions, p > .596. Affective valence did not show a significant condition-by-time interaction indicating comparable changes between conditions, $F(2, 28) = 0.41$, p = .669, part. $\eta^2 = 0.03$.

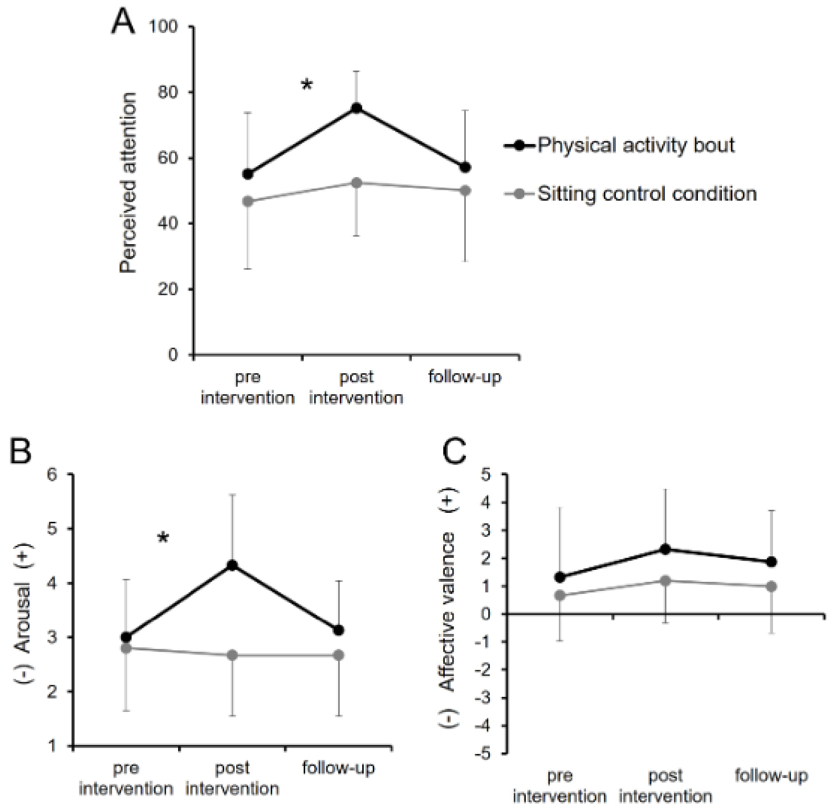

Figure 4

Perceived attention (A), perceived arousal (B), and affective valence (C) separated by condition

*: significant time-by-condition interaction. Dots represent group mean values and error bars indicate standard deviations. Lower values indicate lower perceived attention, lower perceived arousal, and lower affective valence

Retained information and satisfaction with the intervention

Mean percentage of correctly answered response options at follow-up was similar between the physically active condition (71.5% [SD: 12.2%]) and the sitting condition (76.1% [SD: 12.1%]), z = 1.25, p = .211, r = 0.23.

The difference in mean probability of recommending the physically active condition to a friend (5.4 [SD: 2.2]) was not significantly different compared to the sitting condition (4.5 [SD: 2.0]), z = -1.17, p = .244, r = -0.21. The probability of integrating the physically active condition in everyday life (6.1 [SD: 3.2]) was rated similar to the sitting condition (4.9 [SD: 3.0]), z = -0.91, p = .362, r = -0.17. The qualitative questions asked at the end of the study revealed that 66.7% (n = 10) participants preferred the PA bout compared to the sitting condition. Requested adaptions to the PA bout were lower intensity (mentioned by 40.0%), running outdoors (mentioned by 26.7%), and other modalities of PA (e.g., ball games, yoga, stretching, coordinative, or strength exercises; mentioned by 53.3%).

Discussion

The primary aim of the present study was to investigate the effect of a physical activity intervention on cognitive abilities with simultaneous consideration of behaviorally important variables (affect, perceived efficacy). The main findings suggest that cognitive aspects are positively influenced immediately after, but not 30 minutes following a short physical activity bout. This transient benefit was not accompanied with more positively valenced affect compared to the sitting bout, what would be desirable from a behavioral perspective. The findings on satisfaction with the interventions did not show a clear direction. Although the majority of the participants preferred the physically active condition, the probability of integrating the break conducted earlier was rated similar between the physically active and the sitting break. Furthermore, several adaptations of the physically active break were requested.

Cognition after physical activity bouts

The finding on short-term improved cognition after a PA bout fits well to previous findings. Several meta-analyses across various populations and age ranges reported positive acute effects of PA on cognitive abilities (Chang et al., 2012; Janssen et al., 2014; Ludyga et al., 2016). The effect size of the present study converts to a Cohen's . of 1.37 (Cohen, 1988), which is large compared to the small-to-moderate effects reported in meta-analyses. A reason for this discrepancy might be found in the rather simple group test used in the present study, which assesses a combination of several domains of cognition and does not allow to conclude on a single component of cognition. The largest effect sizes were reported for the attentional domain, . = 0.42, (Chang et al., 2012), but significant benefits were also reported for reaction time (Ludyga et al., 2016) and working memory (Hsieh et al., 2021). All of these basic components are utilized when completing the Zahlen-Verbindungs-Test (Schellig et al., 2009). It seems that beneficial effects of PA bouts might be found rather in basic domains of cognition and less in higher order cognitive domains, e.g., reasoning, problem solving, or cognitive flexibility (Aly & Kojima, 2020; Xie et al., 2020).

Short PA bouts, i.e., less than ten minutes, were rarely studied in the previous literature, where predominantly PA bouts with a longer duration between 16 and 35 minutes are used (Pontifex et al., 2019). These longer PA bouts are not feasible during study courses. By the present results assessed in the university context of a study course, previous findings on short breaks could be confirmed (Kao et al., 2017; Niedermeier et al., 2020). In a sample of 64 young adults, a nine-minute bout of high intensity interval training was similarly effective to a 20-

minute bout of continuous aerobic exercise to improve reaction time compared to a sitting rest condition (Kao et al., 2017). The high intensity interval bout yielded superior results compared to the continuous aerobic exercise bout in accuracy involving mainly inhibitory control domain of cognition (Kao et al., 2017). Although it was suggested previously that a minimum threshold duration (longer than 20 minutes) of the PA bout is needed for positive effects on cognition (Chang et al., 2012), short bouts should be considered in the university context, wherever longer bouts are not possible (e.g., during a short break in longer study courses).

It is desirable that the beneficial effects of a PA bout on cognition are lasting longer. However, the present results suggest only a transient effect. Although we did not assess visual attention at follow-up 30 minutes after the intervention to avoid familiarization effects (McCaffrey & Westervelt, 1995), the data on retained information of the first part of the study course (following PA bout: 71.5% correct answers, following sitting condition: 76.1% correct answers) do not suggest a longer-term effect of PA on cognition. In line with this observation, Chang et al. (2012) reported significantly positive effects only, when cognition was assessed up to 15 minutes after the PA bout. When assessed later than 15 minutes after the PA bout, null findings were reported (Chang et al., 2012). Potential mechanisms for acute changes in cognition following single physical activity bouts were beyond the scope of the present study; however, Pontifex et al. (2019) suggested the following mechanisms based on previous literature: An increased arousal, an activation of the locus coeruleus norepinephrine system, catecholamine release, increased cerebral blood flow, and increased neurotrophic factors (e.g., brain-derived neurotrophic factor). The authors critically acknowledge that these potential explanations are yet to be investigated and that the neurobiological mechanisms are not well understood (Pontifex et al., 2019). The present study adds data for a short-term increased arousal after the physically active bout. However, it remains unclear, if increased arousal can be seen as an explaining factor or as a side effect of the physically active bout.

Behavioral aspects

The probability of implementing a specific activity during short breaks in the students' everyday life might be increased when the activity meets certain characteristics: Both a more pleasurable state (Williams et al., 2008) and a higher perceived efficacy (Fishbein & Ajzen, 2010; Schwarz et al., 2016) are believed to result in increased adherence to the behavior. In the present study, a higher perceived efficacy was found after the PA bout, what might be considered as a favorable development for the implementation of PA bouts in the everyday life. However, in contrast to perceived efficacy, the results on affective valence cannot be considered favorable since the PA bout was not associated with a higher state of pleasure. Williams et al. (2008) investigated the importance of valence in relation to future PA behavior and reported an increase of

38 minutes of PA per week by increasing valence by one point on the Feeling Scale. Therefore, an increase in affective valence after the activity in breaks is desirable. The satisfaction with the intervention must be considered as mixed: Although the majority of the participants reported to prefer the PA bout compared to the sitting bout, no significant differences were found in recommending the conditions to a friend or in integrating the bouts in everyday life. Therefore, it seems important considering individual preferences for PA also for activity in short breaks as reported previously (Sudeck & Conzelmann, 2011). From a behavioral perspective, this result has consequences both for students and teachers. Teachers are recommended to provide a framework for physically active short breaks (e.g., adequate duration of the break, possibility to leave the classroom during the breaks, suggestions for PA modalities); however, teachers should not insist on a specific PA modality to avoid not meeting the student's preferences. Students are recommended to select a pleasurable PA modality in short breaks.

Running indoors with an intensity tapping the lower level of vigorous range was used for the PA bout of the present study (American College of Sports Medicine, 2018). The intensity chosen might be considered as too high since nearly half of the sample requested a lower intensity. Although a higher intensity could be a more time-efficient option for improving cognitive abilities (Kao et al., 2017), a self-selected intensity might be recommended for short breaks from a behavioral perspective. Environmental aspects, e.g., conducting PA outdoors (Niedermeier et al., 2017), and preferences for different PA modalities (Sudeck & Conzelmann, 2011), e.g., stretching, coordinative, or strength exercises, should also be considered. Potential differential cognitive effects of various vigorous-intense PA modalities are yet to be investigated (Hsieh et al., 2021). Since three out of four most frequently conducted break routines of the present sample are usually done in sitting posture (see Figure 2), it seems important to consider alternatives for PA intensity and modality.

Limitations and strengths

The following limitations have to be considered when interpreting the present finding. Firstly, and most importantly, the present sample size is relatively small. Although the applied crossover design increases statistical power, the chance for a false-positive finding is still high. Secondly, the primary outcome was assessed with a relatively simple group test and the test was applied only immediately post intervention. We did not collect data on cognition pre-intervention or at follow-up to avoid unintended familiarization effects (McCaffrey & Westervelt, 1995). However, an assessment of cognition pre-intervention would allow to control for daily fluctuations and an assessment at follow-up would help to gain insight in potential longer-term effects. Thirdly, the present results cannot be generalized beyond the sample of sport students. The lack of transferability also includes students of other study courses. The PA level of the present sample is similar compared to other departments of sport science, where a mean of 7700 MET minutes per week for total PA was reported prior to the Covid-19 pandemic (Öncen & Tanyeri, 2020), but high compared to the minimal amount of PA recommended, i.e., 500-1000 MET minutes per week (American College of Sports Medicine, 2018). It remains unclear, how students with a lower PA level react especially to the vigorous intensity of the PA bout.

The simultaneous consideration of efficacy (i.e., visual attention) and behaviorally important variables (e.g., perceived efficacy and affective states) is seen as a strength of the present study. Furthermore, we see the within-subject design to control for inter-individual variation and the contribution to the small amount of studies referring to short bouts of PA as strengths of the study.

Conclusión

The present findings suggest a short-term positive effect of a short vigorous-intense physical activity bout on basic domains of cognition in the population of sport students with a high level of physical activity. As such, vigorous-intense physical activity is a relatively easy-to-integrate intervention in short breaks during everyday life of students of sport science, specifically prior to cognitively challenging study tasks. The option of a short physically active break should also be considered by teachers when a difficult topic is started during a study course. However, the physical activity applied (running indoors) did not show consistent favorable effects on variables connected behavior. Therefore, self-selected modality and/or self-selected intensity of the physical activity bout might show a higher potential to be implemented in sport science students' everyday life. Given the above-average amount of physical activity of sport students and the vigorous intensity of the physical activity bout, the present results should not be generalized beyond the sample of sport students. Future research might focus on the comparison of different physical activity modalities and different environments.

References

Aly, M. & Kojima, H. (2020). Acute moderate-intensity exercise generally enhances neural resources related to perceptual and cognitive processes: A randomized controlled ERP study. *Mental Health and Physical Activity, 19*: 100363. https://doi.org/10.1016/j.mhpa.2020.100363

American College of Sports Medicine. (2018). *ACSM's Guidelines for Exercise Testing and Prescription* (10th ed.). Philadelphia: Lippincott: Williams, & Wilkins.

Baker, R., Coenen, P., Howie, E., Williamson, A. & Straker, L. (2018). The short term musculoskeletal and cognitive effects of prolonged sitting during office computer work. *International Journal of Environmental Research and Public Health, 15*: 1678. https://doi.org/10.3390/ijerph15081678

Borg, G. (1982). Psychophysical bases of perceived exertion. *Medicine & Science in Sports & Exercise 14*, 377-381.

Borg, G. (1998). *Borg's perceived exertion and pain scales*. Champaign: Human Kinetics.

Chang, Y. K., Labban, J. D., Gapin, J. I. & Etnier, J. L. (2012). The effects of acute exercise on cognitive performance: A meta-analysis. *Brain Research, 1453*, 87-101. https://doi.org/10.1016/j.brainres.2012.02.068

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2nd ed.). Hillsdale: Lawrence Erlbaum Associates.

Craig, C. L., Marshall, A. L., Sjostrom, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E. ... & Oja, P. (2003). International physical activity questionnaire: 12-country reliability and validity. *Medicine & Science in Sports & Exercise, 35*, 1381-1395. https://doi.org/10.1249/01.mss.0000078924.61453.fb

Ekelund, U., Steene-Johannessen, J., Brown, W. J., Fagerland, M. W., Owen, N., Powell, K. E. ... & Lee, I. M. (2016). Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis of data from more than 1 million men and women. *The Lancet, 388*, 1302-1310. https://doi.org/http://dx.doi.org/10.1016/s0140-6736(16)30370-1

Elbourne, D. R., Altman, D. G., Higgins, J. P., Curtin, F., Worthington, H. V. & Vail, A. (2002). Meta-analyses involving cross-over trials: Methodological issues. *International Journal of Epidemiology, 31*, 140-149.

Faul, F., Erdfelder, E., Lang, A. G. & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *BehaviorResearch Methods, 39*, 175-191.

Felez-Nobrega, M., Hillman, C. H., Dowd, K. P., Cirera, E. & Puig-Ribera, A. (2018). ActivPAL determined sedentary behaviour, physical activity and academic achievement in college students. *Journal of Sports Sciences, 36*, 2311-2316. https://doi.org/10.1080/02640414.2018.1451212

Fishbein, M. & Ajzen, I. (2010). *Predicting and changing behavior: The reasoned action approach*. New York: Psychology Press.

Hardy, C. J. & Rejeski, W. J. (1989). Not what, but how one feels: The measurement of affect during exercise. *Journalof Sport and Exercise Psychology, 11*, 304-317.

Hsieh, S. S., Chueh, T. Y., Huang, C. J., Kao, S. C., Hillman, C. H., Chang, Y. K. & Hung, T. M. (2021). Systematic review of the acute and chronic effects of high-intensity interval training on executive function across the lifespan. *Journal of Sports Sciences, 39*, 10-22. https://doi.org/10.1080/02640414.2020.1803630

Janssen, M., Toussaint, H. M., van Mechelen, W. & Verhagen, E. A. (2014). Effects of acute bouts of physical activity on children's attention: A systematic review of the literature. *SpringerPlus, 3*: 410. https://doi.org/10.1186/2193-1801-3-410

Juren, Y. U., Soh, K. G., Soh, K. L. & Ong, S. L. (2020). Comparing sitting time between male and female undergraduate students during weekdays and weekends. *European Journal of Molecular & Clinical Medicine, 7*(3), 79-87.

Kao, S. C., Westfall, D. R., Soneson, J., Gurd, B. & Hillman, C. H. (2017). Comparison of the acute effects of high-intensity interval training and continuous aerobic walking on inhibitory control. *Psychophysiology, 54*, 1335-1345. https://doi.org/10.1111/psyp.12889

Ludyga, S., Gerber, M., Brand, S., Holsboer-Trachsler, E. & Pühse, U. (2016). Acute effects of moderate aerobic exercise on specific aspects of executive function in different age and fitness groups: A meta-analysis. *Psychophysiology, 53*, 1611-1626. https://doi.org/10.1111/psyp.12736

Maibach, M., Niedermeier, M., Sudeck, G. & Kopp, M. (2020). Erfassung unmittelbarer affektiver Reaktionen auf körperliche Aktivität: Eine Validierungsstudie für deutschsprachige Versionen der Feeling Scale und der Felt Arousal Scale [Measuring acute affective responses to physical activity: A validation study of German versions of the Feeling Scale and Felt Arousal Scale]. *Zeitschrift für Sportpsychologie, 27*, 4-12. https://doi.org/10.1026/1612-5010/a000291

McCaffrey, R. J. & Westervelt, H. J. (1995). Issues associated with repeated neuropsychological assessments. *NeuropsychologyReview, 5*, 203-221.

Mullane, S. L., Buman, M. P., Zeigler, Z. S., Crespo, N. C. & Gaesser, G. A. (2017). Acute effects on cognitive performance following bouts of standing and light-intensity physical activity in a simulated workplace environment. *Journalof Science and Medicine in Sport, 20*, 489-493. https://doi.org/10.1016/j.jsams.2016.09.015

Niedermeier, M., Einwanger, J., Hartl, A. & Kopp, M. (2017). Affective responses in mountain hiking - A randomized crossover trial focusing on differences between indoor and outdoor activity. *PloS One, 12*: e0177719. https://doi.org/10.1371/journal.pone.0177719

Niedermeier, M., Weiss, E. M., Steidl-Müller, L., Burtscher, M. & Kopp, M. (2020). Acute effects of a short bout of physical activity on cognitive function in sport students. *International Journal of Environmental Research and Public Health, 17*: 3678. https://doi.org/10.3390/ijerph17103678

Öncen, S. & Tanyeri, L. (2020). Evaluation of the physical activity levels of the students in a physical education and sports science department before and during the coronavirus pandemic. *International Education Studies, 13*(10), 148-156. https://doi.org/10.5539/ies.v13n10p148

Oswald, W. (2016). *Zahlen-Verbindungs-Test ZVT* (3rd ed.). Göttingen; Hogrefe.

Petruzzello, S. J. & Box, A. G. (2020). The kids are alright — Right? Physical activity and mental health in college students. *Kinesiology Review, 9*, 279-286. https://doi.org/10.1123/kr.2020-0039

Pontifex, M. B., McGowan, A. L., Chandler, M. C., Gwizdala, K. L., Parks, A. C., Fenn, K. & Kamijo, K. (2019). A primer on investigating the after effects of acute bouts of physical activity on cognition. *Psychology of Sport and Exercise, 40*, 1-22. https://doi.org/10.1016/j.psychsport.2018.08.015

Reichheld, F. F. (2003). The one number you need to grow. *Harvard Business Review, 81*(12), 46-54, 124.

Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology, 39*, 1161-1178. https://doi.org/10.1037/h0077714

Schellig, D., Drechsler, R., Heinemann, D. & Sturm, W. (2009). *Handbuchneuropsychologischer Testverfahren. 1. Aufmerksamkeit,* *Gedächtnis und exekutive Funktionen* [Handbook of neuropsychological test procedures. 1. Attention, memory and executive functions.]. Göttingen: Hogrefe.

Schwarz, K. A., Pfister, R. & Buchel, C. (2016). Rethinking explicit expectations: Connecting placebos, social cognition, and contextual perception. *Trendsin Cognitive Sciences, 20*, 469-480. https://doi.org/10.1016/j.tics.2016.04.001

Senn, S. (2002). *Cross-over trials in clinical research*. Hoboken: John Wiley & Sons. https://doi.org/10.1002/0470854596

Sudeck, G. & Conzelmann, A. (2011). Motivbasierte Passung von Sportprogrammen: Explizite Motive und Ziele als Moderatoren von Befindlichkeitsveränderungen durch sportliche Aktivität [Motive-based tailoring of sports programmes: Explicit motives and goals as moderators of mood changes through sports activities]. *Sportwissenschaft, 41*: 175.

Svebak, S. & Murgatroyd, S. (1985). Metamotivational dominance: A multimethod validation of reversal theory constructs. *Journalof Personality and Social Psychology, 48*, 107-116.

Tombaugh, T. (2004). Trail Making Test A and B: Normative data stratified by age and education. *Archives of Clinical Neuropsychology, 19*, 203-214. https://doi.org/10.1016/s0887-6177(03)00039-8

Triglav, J., Howe, E., Cheema, J., Dube, B., Fenske, M. J., Strzalkowski, N. & Bent, L. (2019). Physiological and cognitive measures during prolonged sitting: Comparisons between a standard and multi-axial office chair. *Applied Ergonomics, 78*, 176-183. https://doi.org/10.1016/j.apergo.2019.03.002

Williams, D. M., Dunsiger, S., Ciccolo, J. T., Lewis, B. A., Albrecht, A. E. & Marcus, B. H. (2008). Acute affective response to a moderate-intensity exercise stimulus predicts physical activity participation 6 and 12 months later. *Psychology of Sport and Exercise, 9*, 231-245. https://doi.org/10.1016/j.psychsport.2007.04.002

Xie, C., Alderman, B. L., Meng, F., Ai, J., Chang, Y. K. & Li, A. (2020). Acute high-intensity interval exercise improves inhibitory control among young adult males with obesity. *Frontiers in Psychology, 11*: 1291. https://doi.org/10.3389/fpsyg.2020.01291