Original Article

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Acute Effects of Exercise Breaks on Attention and Working Memory During a University Lecture: A Group-Randomized Controlled Trial

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Abstract:

Objective: This study investigated the acute effects of exercise breaks on attention and working memory during lectures among third-year physical therapy students.

Material and Methods: In total 65 participants were randomly assigned to exercise breaks (N=22), game breaks (N=21), and no breaks (N=22). The lecture was divided into two parts. Participants watched each part of a 50-minute computer-based video lecture. The present study examined the heart rate, perception, attention, and working memory impact of 5-minute breaks. The exercise breaks group performed a series of callisthenic exercises, the game breaks group played a computer game, and the no breaks group watched the entire lecture continuously without breaks. The differences in means for variables among each group were compared using a 3x2 repeated measure Multivariate Analysis of Covariance (MANCOVA).

Results: Exercise breaks during lectures facilitated a positive impact on the modulation of shifting working memory in comparison to game breaks and non-exercise breaks (p-value<0.05). Significant pre-test to post-test in shifting working memory improvements were found in the exercise breaks group ($F(2,62)=4.266$, p-value=0.018). The variation in mean shifting working memory was 12.1 percent of the effect ($n_p^2=0.121$). This improvement aligned with better learning results, especially when assessed for immediate outcomes.

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Conclusion: Exercise breaks during academic lectures demonstrated a statistically significant impact on shifting working memory. Consequently, further investigations are required to explore the enduring impacts of exercise breaks on cognitive functions in the long term. Additionally, determining the optimal duration of exercise breaks and lecture lengths is essential for guiding university teaching practices.

Keywords: attention, exercise breaks, lecture, working memory

Introduction

Presently, university-level teaching predominantly relies on lecture-based methods, demanding that students sustain attention for extended periods to grasp learning materials: an often challenging task for most students. Numerous studies emphasize the critical role of student attention in learning effectiveness[1-3]. Interestingly, students typically devote only around 30% of their time to focused attention during lectures[4,5]. University lectures, lasting approximately 2-3 hours per course, can contribute to distraction due to prolonged sitting periods. Attention span during studying is limited to 10-15 minutes, with some studies suggesting an optimal study duration of 20 minutes[1]. When attention decreases during lectures, the efficiency of memory retention diminishes, leading to a negative impact on learning and reduced overall learning efficiency[6].

Previous studies have shown that exercise breaks, which are calisthenic exercises, have a direct effect on the brain by increasing arousal through the release of hormones wherein stress hormones increase attention and memory[7,8]. The hypothalamus–pituitary–adrenal (HPA) secretes hormones to stimulate the adrenal cortex to secrete glucocorticoids, which are hormones that affect cognitive function[9]. In this study bodyweight exercises were used as a resistance (calisthenic exercise)[10]. The body that has practiced more new postures by doing this type of exercise can help increase attention[10]. Moreover, exercise with music in a rhythm of 136-139 beats per minute (bpm)[11] has been shown to influence learning and attention. Studies concerning the relationship between music and learning have found that music can enhance cognitive abilities[12], such as attention and memory, through mechanisms of increasing arousal and a positive mood[13]. Preliminary studies have suggested that a fast tempo has a more pronounced impact on cognition compared to a slow tempo[14]. However, in Thailand, there has been no exploration of the effects of exercise breaks during learning on attention and memory for providing valuable guidance in university teaching practices. Therefore, this study aimed to determine the intermediate effect of exercise breaks on attention and working memory during a video lecture at the university. It was hypothesized that the exercise breaks group would have a significantly higher performance in attention and working memory than the game break and non-exercise breaks groups.

Material and Methods

Study design

This study was a group-randomized controlled trial design, conducted from January to July 2021. It included an exercise breaks group, a game breaks group, and a no breaks or control group. Variables including heart rate, perception, attention, working memory, and academic achievement, were measured pre-test and post-test.

Participants

All participants were recruited from the Department of Physical Therapy, Mae Fah Luang University, Chiang Rai province, Thailand. The participants were sampled by cluster random sampling. The most vital processes involved random selection and random assignment. All participants were arranged according to grade point average (GPAX), from highest to lowest, and then grouped into groups with an average of similar GPAX; with no significant differences among the three groups.

The sample size was calculated by using a sampling package program. via an Excel program. The experimental effect size (ES) was equal to 0.4, the number of experimental methods was equal to 3 methods and the degrees of freedom (df) were equal to 2: which was calculated from a sample size of 63 participants[15]. The inclusion criteria were as follows: students at Mae Fah Luang University enrolled in the Physical Therapy in Neurology System course and agreed to participate in the project. The exclusion criteria were as follows: history of cardiovascular and respiratory diseases; such as asthma or heart disease for at least 1 year, pain; such as knee pain, back pain or foot pain for 3 months (Pain level VAS>5/10), accident in the spine or hip surgery in the past 1 year, taking any drugs that affect the nervous system, having consumed alcohol or caffeinated beverages within 24 hours before participating in the experiment[16,17].

Procedure

Participants were randomly assigned into either the exercise breaks (N=22), game breaks (N=21), and no breaks (N=22) groups, with the lecture being divided into two parts. Participants watched each part of a 50-min computer-based video lecture. The present study examined the heart rate, perception, attention and working memory impact of 5-minute breaks. The exercise breaks group performed a series of callisthenic exercises (twitch jump, jumping jack, high knee, abdominal bike and squat), the game breaks group played a computer game (Bejeweled and matching game) and the no breaks group watched the lecture

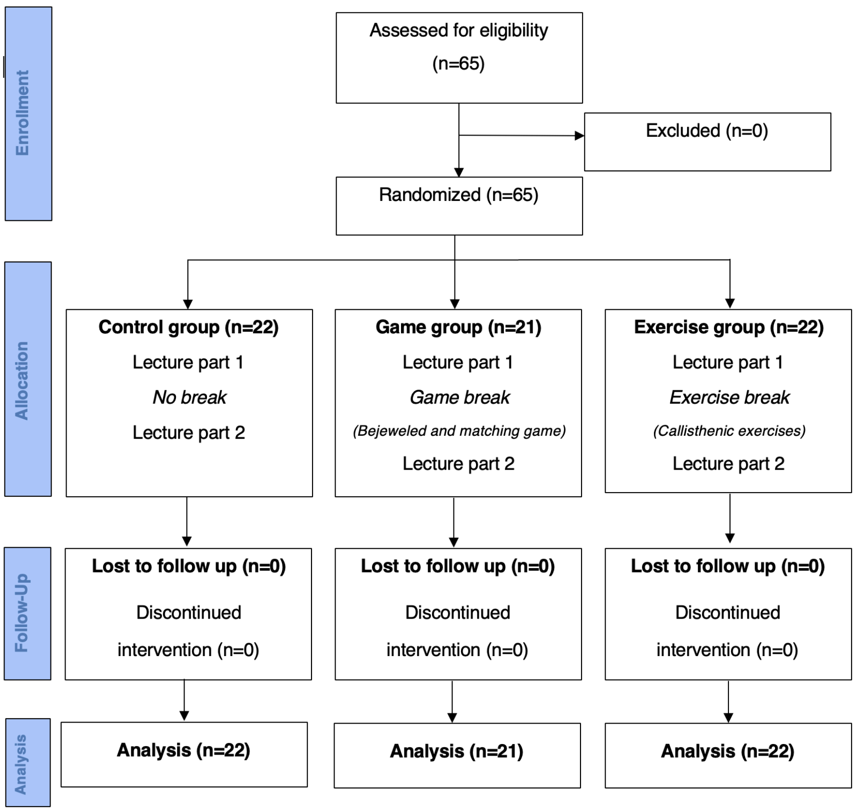

Figure 1 The CONSORT diagram

continuously without breaks. The CONSORT diagram is presented in Figure 1. The study was approved by the human ethics committee of Mae Fah Luang University (EC 20193-25). All 65 participants provided informed consent before participation.

Exercise breaks consisted of a series of callisthenic exercises (twitch jump, jumping jack, high knee, abdominal bike and squat), with music set at a 136-139 bpm rhythm The index of item-objective congruence (IOC) was 0.928.

Heart rate was measured by using the Polar H10 heart rate sensor, with a chest strap device (Polar Electro, Malaysia; 5kHz transmission), having good validity (intraclass correlation coefficient (ICC)=0.84)[18].

Perception was assessed using a self-subjective perception assessment, with a 7-Likert scale. The face validity of this instruments is the index of IOC between 0.67–1.00[19]. It consists of 5 components (a total of 25 items) as follows: perception of interest (5 items), perception of understanding (5 items), teachers' perception of clarity (5 items), perception of difficulty (5 items) and perception of stimulation (5 items).

Attention and working memory were evaluated using the cognitive ability test software, which consists of 8 tests. Each test is comprised of 30 items designed to measure cognitive ability, with two variables: attention (simple reaction time, focused attention, selected attention and sustained attention) and working memory (basic processing, shifting working memory, updating working memory and inhibited working memory); resulting in four variables per test. The student is required to respond correctly, while minimizing the time taken. This instrument was confirmed to have construct validity, as an excellent fit. The fitness index for validating the cognitive ability test software was as follows: c^2statistic of 18.295 (degrees of freedom=13, p-value=0.143), and the c^2/df ratio having a value of 1.407; indicating a good fit. The comparative fit index (CFI) was 0.999, and the Tucker-Lewis coefficient (TLI) was 0.997, the Root Mean Square Error Approximation (RMSEA) was 0.016, and the Standardized Root Mean Residual (SRMR) was 0.014[20].

Academic achievement was measured by a 10-item multiple choice test; it consisted of a 4-choice answer; with a consistency index of 5 experts ranging from 0.80 to 1.00: its reliability was 0.80.

Statistical analysis

The analysis was conducted using Statistical Package for the Social Science (SPSS) statistical software version 20.0, and a significance level of a p-value<0.05 was applied. The normality of the data was assessed using the Kolmogorov-Smirnov test. Descriptive statistics was used for demographic data reported as mean and standard deviation. The differences in means for the dependent variables (heart rate, perception, attention, memory, and academic achievement) among each group were compared using a 3x2 repeated measure Multivariate Analysis of Covariance (MANCOVA).

Results

The demographic characteristics of participants are presented in Table 1. There were no significant differences in the demographic characteristic variables (age, body mass index and grade point average): as shown in Table 1.

Working memory

The comparison results of the working memory between the exercise breaks, game breaks, and control group are presented in Table 2.

When comparing working memory before and after studying lectures among the exercise groups, game groups, and control groups, it was observed that there were no differences in the three components: basic processing of working memory, updating working memory, and inhibiting working memory. However, significant pre-test to post-test in shifting working memory improvements were found for the exercise breaks group (F(2,62)=4.266, p-value=0.018), as shown in Table 2. The variation in mean shifting working memory was 12.1 percent of the effect (n_p^2=0.121).

Heart rate (HR)

The comparison results of the mean heart rate between the exercise breaks, game breaks, and the control group are presented in Table 3.

Table 3 displays the study results; comparing the mean HR in beats per minute (bpm) after resting among the exercise groups, game groups, and control group. Significant differences in heart rate were observed in the exercise breaks group; at the 0.05 level ($F(2,62)=111.182$, p-value<0.001), indicating the impact of the braking activity. The variation in mean heart rate was 78.2 percent of the effect ($\eta_p^2=0.782$).

Table 1 Demographic characteristics of participants

Variables	Exercise group M (S.D.) N=22	Game group M (S.D.) N=21	Control group M (S.D.) N=22	p-value
Age (years)	20.91 (0.53)	21.14 (1.42)	21.18 (0.73)	0.602
Body mass index (kg/m^2)	20.91 (3.95)	24.12 (5.97)	22.56 (4.60)	0.107
Grade point average	3.13 (0.34)	3.13 (0.32)	3.15 (0.35)	0.980

S.D.=standard deviation, M=mean, kg/m^2=kilogram per square meter

Table 2 Working memory before and after lectures

Variables	Accuracy			
	Exercise group M (S.D.)	Game group M (S.D.)	Control group M (S.D.)	p-value
Basic processing				
Pre-test	28.818 (1.651)	29.048 (1.117)	27.818 (5.671)	
Post-test	29.273 (0.767)	29.619 (0.590)	27.909 (6.094)	0.260
Shifting working memory				
Pre-test	26.818 (3.487)	28.524 (1.030)	26.455 (3.158)	
Post-test	28.318 (1.249)*	28.285 (1.146)	26.682 (3.228)	0.018
Updating working memory				
Pre-test	19.591 (6.645)	22.619 (6.719)	19.955 (7.780)	
Post-test	24.409 (5.941)	26.619 (4.685)	24.864 (6.349)	0.416
Inhibition working memory				
Pre-test	27.636 (5.215)	28.143 (3.610)	27.727 (4.968)	
Post-test	28.818 (1.140)	29.000 (1.140)	29.000 (0.816)	0.802

S.D.=standard deviation, M=mean, *p-value<0.05 significant difference compared with game group and control group

Table 3 Heart rate before and after breaks between lectures

Variables	Exercise group M (S.D.)	Game group M (S.D.)	Control group M (S.D.)	p-value
Heart rate				
Pre-heart rate	86.682 (14.076)	86.095 (1.609)	77.091(10.263)	
Post-heart rate	139.500 (23.628)*	83.714 (9.598)	71.591(11.027)	<0.001

S.D.=standard deviation, M=mean, *p-value<0.001 significant difference compared with game group and control group

Table 4 Perception before and after lectures

Variables	Exercise group M (S.D.)	Game group M (S.D.)	Control group M (S.D.)	p-value
Perception				
Pre-test	4.549 (1.099)	5.366 (0.899)	4.975 (1.329)	
Post-test	5.189 (1.080)	5.482 (1.120)	5.262 (1.001)	0.649

S.D.=standard deviation, M=mean

Table 5 Attention before and after lectures

Variables	Accuracy			
	Exercise group M (S.D.)	Game group M (S.D.)	Control group M (S.D.)	p-value
Simple reaction time				
Pre-test	29.909 (0.426)	29.952 (0.218)	29.636 (0.953)	
Post-test	29.955 (0.213)	30.000 (0.000)	29.909 (0.294)	0.376
Focus attention				
Pre-test	29.182 (0.795)	29.524 (0.928)	28.818 (1.220)	
Post-test	29.545 (0.671)	29.476 (0.750)	27.955 (2.591)	0.102
Selected attention				
Pre-test	28.955 (1.090)	29.190 (0.814)	29.091 (0.971)	
Post-test	29.273 (1.120)	29.048 (1.161)	28.773 (1.020)	0.327
Sustain attention				
Pre-test	29.591 (0.666)	29.571 (0.676)	29.364 (0.658)	
Post-test	29.318 (1.171)	29.476 (0.680)	29.182 (1.296)	0.676

S.D.=standard deviation, M=mean

Table 6 Achievement before and after lectures

Variable	Exercise group M (S.D.)	Game group M (S.D.)	Control group M (S.D.)	p-value
Achievement				
Pre-achievement	4.318 (2.033)	3.667 (1.713)	4.227 (1.602)	
Post-achievement	6.273 (1.352)	6.095 (1.609)	6.182 (1.468)	0.925

S.D.=standard deviation, M=mean

Perception

The comparison results of the perception between the exercise breaks, game breaks, and control group are presented in Table 4.

Table 4 reveals that differences were observed between the exercise groups, game groups, and control group when comparing perception before and after the lecture class. However, they were not statistically significant ($F(2,62)=0.436$, p-value=0.649).

Attention

The comparison results of the attention between the exercise breaks, game breaks, and control group are presented in Table 5.

Table 5 reveals that when comparing attention before and after the lecture class among the exercise groups, game groups, and control group no significant differences in simple reaction time, focused attention, selected attention and sustained attention were observed.

Achievement

The comparison results of the achievement between the exercise breaks, game breaks, and control group are presented in Table 6.

From Table 6, the comparison of academic achievement before and after studying lectures for all three groups reveals that there is a non-statistically significant difference when assessing learning outcomes before attending the lecture section between the exercise groups, game groups, and control group ($F(2,62)=0.078$, p-value=0.925).

Discussion

This study explores the intermediate effects of exercise breaks in university lectures on the perception, attention and working memory of undergraduate students. The results of measuring arousal through heart rate are the basis for this study. Because of the outcomes associated with moderate exercise intensity falling within 50% to 70% of the maximum heart rate (HRmax), or 3.0 to less than 6.0 metabolic equivalents tasks (METs), in addition to considering the influence of music tempo on arousal, when evaluating alertness before and after the lecture by monitoring heart rate; it was noted that the exercise groups demonstrated a significant increase in heart rate compared to both the game breaks groups and the control group. This was by using the principles of exercise to stimulate hypothalamus–pituitary–adrenal, which influences memory in situations with acute stress in which the HPA releases the hormone adrenocorticotrophin hormone (ACTH). This result supports the HPA activation hypothesis, suggesting that the arousal induced by exercise contributes to releasing stress hormones that enhance attention and memory[7,21,22].

When contrasting the tempos of fast and slow music, it was noted that fast tempos significantly enhance alertness. Consequently, the exercise groups demonstrated an increased heart rate. Given the influence of emotional states, encompassing both arousal and mood on cognition, it is evident that a faster rhythm exerts a more substantial effect on cognitive processes than a slower rhythm[14]. Furthermore, this present study examined the attention and learning impact of 5-minute breaks distributed throughout a 50-minute computer-based video lecture.

An earlier investigation demonstrated that participants engaged in 50-minute lectures with a 5-minute exercise break revealed a statistically significant improvement in the participants' attention, memory and learning[23]. Other studies examining the relationship between physical activity and attention and cognitive ability also reported similar positive effects when employing various exercise durations. Tsukamoto, et al. 2016 study, incorporating a 16-minute exercise, and Alves, et al. 2014 study, involving a 10-minute exercise, demonstrated comparable increases in focus and memory. Likewise, Kao, et al. 2017 study employed a 9-minute workout, showcasing similar positive outcomes[24-26]. A previous study revealed that regular physical exercise during the morning break over four weeks (5 units per week) improves academic performances and cognitive functions in concentration ability and ideational fluency[27]. Moreover, engaging in physically challenging games in 45-minute sessions that stimulate cognitive functions can effectively improve executive functions and encourage students to participate in enjoyable and interesting forms of physical activity[28].

This present study demonstrates that no significant differences in attention and working memory were observed in the game breaks (non-exercise breaks) group. However, non-exercise breaks that elicit similar levels of interest and learning can be beneficial in practical scenarios; especially for students or learning environments that have restrictions on physical activity. Moreover, incorporating short exercise breaks between content presentations contributes to enhancing learning experiences in both traditional classroom settings and online environments[23]. Students participated in lectures in this study based on their individual preferences for learning styles[29]. Previous studies indicate that switching to alternative learning styles; such as vocabulary study or video learning, enhances cognition and learning compared to traditional lectures[30,31]. Consequently, adopting video learning may lead to better retention of lessons.

This pilot study demonstrates that the advantages of exercise breaks during classroom sessions for working memory also apply to young adults. The limitation of this study is that it might not be practical to do these exercises in university lectures; especially in small classrooms having limited space. Future research should explore whether exercises that require minimal physical space can generate similar benefits in terms of interest and learning. Moreover, it is crucial to ascertain the suitable duration for exercise breaks and lecture lengths to align with the specific teaching context and practices in a long-term study, which could provide valuable guidance for university teaching practices.

Conclusion

Exercise breaks during academic lectures demonstrated a statistically significant impact on shifting working memory. Although attention and perception remained statistically unaffected compared to both the game breaks and the control group, it is crucial to note that this investigation specifically focused on the immediate effects of an exercise break. Consequently, further investigations are required to explore the enduring impacts of exercise breaks on cognitive functions in the long term.

Conflict of interest

The authors declare no conflicts of interest.

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