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中等運動強度的有氧運動對認知變通的影響

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摘要

執行身體活動的常規生活方式被認為是可以防止認知功能的減退，更有可能可以提高認知功能。本研究的主要目的是探討有氧運動對大學生之認知功能表現的影響。參加者是32名年輕健康但沒有規律運動習慣的成人，年齡範圍為20－30歲，（M年齡 = 21.78，SD = 1.88），就讀於臺灣中部的一所大學。他們被隨機分配到運動組或不運動組，各組有同等數量的男性*（n = 8）和女性（n = 8）學生。在這4週的有氧運動介入，運動組需進行每週3天，每天時間為50分鐘的有氧運動，而不運動組需保持原來不運動的生活形態與習慣。測量結果為認知變通。採用混合二因子變異數分析來進行神經認知數據的分析並比較運動組與不運動組之間的差別：（組 x 時間: 2 x 2）。組和時間F（1,30）= 20.07，p < 0.05，η2= 0.40之間存在著交互顯著。調查發現，經過4週的有氧運動的介入之後，運動組的干擾得分低於不運動組。因此，研究結果表示，規律的中等強度的有氧運動也許能提升認知的表現，特別是對於年輕成人的注意力/專注力。

關鍵詞：有氧運動、認知變通、選擇性注意、史楚普效應

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The Effect of Moderate Aerobic Exercise on Cognitive Flexibility

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Abstract

Performing regular, daily physical activity is believed to prevent cognitive decline and may enhance cognitive functioning. The main purpose of this study is to investigate the effect of aerobic exercise on cognitive functional performance in college students. The participants were 32 healthy young adults within the age range of 20-30 years old (M age = 21.78, SD = 1.88) enrolled at a university in central Taiwan. They were randomly assigned to either an experimental or a control group, with an equal number of male (n = 8) and female (n = 8) students in each group. Over a 4-week aerobic exercise intervention, exercised groups were aerobically active 3 days a week for 50 minutes each time, while the control group remained in an inactive lifestyle. The outcome was to measure cognitive flexibility. Neurocognitive data was analyzed using a (2 x 2: group x time) mixed factorial ANOVA and comparing the control to the exercising group. A significant interaction existed between group and time F (1,30) = 20.07, p < .05, η2 = .40. The investigation shows that the exercising group had lower interference scores than the control group after the exercise program. These findings suggest that regular aerobic exercise may facilitate cognitive performance, particularly in regards to attention/concentration in young adults.

Keywords: aerobic exercise, cognitive flexibility, selective attention, Stroop effect

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Introduction

The study of cognition is an important and growing topic in the field of physical activity and exercise science as cognition affects us all at all ages in a wide range of ways. When children are developing, parents worry whether their children are clever enough to compete with their peers academically. While at work, job performance is constantly a subject in mind. As people age, they forget things easily and worry that someday they may not remember their loved ones. Cognition has an impact on almost all human performance, including learning, job performance, and functions in daily life. Therefore, researchers are interested in finding ways to either maintain cognition or improve it. Exercise is one of areas investigated and it shows promise.

Campus recreation is a service provided by institutions to offer students an opportunity to participate in sports and fitness activities. Students who spent quality time and energy at wellness centers or in sports through campus recreation programs indicated a positive influence on learning and more concentration on their schoolwork (Pace, 1990). Available research evidence indicates that exercise can increase the blood vessels and brain cells, and thus improve blood flow in brain regions which are factors influencing cognitive performance (Colcombe, Erickon, Raz, et al., 2003; Colcombe, Erickon, Scalf, et al., 2006; Guiney, Lucas, Cotter, & Machado, 2015; Masley, Roetzheim, & Gualtieri, 2009).

The findings of previous research studies suggest that exercise has a positive effect on cognitive function in animals, children, middle-aged (50-65 years old), and older adults. However, little attention has been directed to examine such an enhancing effect of exercise on cognition in young adults.

Therefore, the main purpose of the study is to investigate the effect of moderate aerobic exercise on cognitive functioning performance in young adults.

Related Studies

Previous studies revealed that aerobic exercise may delay brain tissue loss and protect against cognitive aging (Colcombe, Erickon, Raz, et al., 2003; Colcombe, Erickon, Scalf, et al., 2006) as well as improve cognitive processing speed (Harveson et al., 2016; Kamijo et al., 2007; Kamijo et al., 2009), enhance attention sustainability in young children (Palmer, Miller, & Robinson, 2013), and strengthen working memory (Cowan et al., 2005; Hillman, Castelli, & Buck, 2005; Stroth, Hille, Spitzer, & Reinhardt, 2009). In a study, Netz, Tomer, Axelrad, Argov, and Inbar (2007) reported that a single aerobic training session might have some beneficial effects on cognitive flexibility in late middle-aged individuals. Kramer and Erickson (2007) claimed that physical activity enhances cognition and brain function after a meta-analysis of both human and animal studies. Recent studies also suggested that exercise and physical activities have positive impacts on cognition in the elderly (Bula, 2016; Heisz & Kovacevic, 2016; Mehtap, Tasgin, Lok, & Lok, 2015; Phillips, Edwards, Andel, & Kilpatrick, 2016). According to Hillman, Erickson, and Kramer (2008), aerobic exercise improves learning and task acquisition, increases the secretion of key neurochemicals associated with synaptic plasticity and promotes the development of new neuronal architecture. As a result, Hillamn et al. (2008) suggested that aerobic exercise is an important lifestyle factor that influences cognitive function throughout the lifespan.

Studies indicate that aerobic exercise also has positive effects for school-aged children (Davis et al., 2007; Naglieri & Das, 1997). Naglieri and Das (1997) studied a group of healthy children (age 7-11) with three levels of intervention: low-dose (20 min/day exercise), high-dose (40 min/day exercise), or no exercise. The learning processes of Planning, attention, simultaneous, and successive (PASS) were measured via a Cognitive Assessment System (CAS). The results show that the high-dose group demonstrated significant greater planning scores which assess the cognitive control, utilization of process, and knowledge of the students. Moreover, not only does chronic aerobic exercise contribute to cognitive functioning but benefits can be found from a single exercise experience. Palmer et al. (2013) assessed the sustained attention of the preschoolers' following a 30-min bout of exercise and a sedentary period. Preschoolers showed a better ability to sustain attention after just a single bout of exercise rather than being sedentary.

Moreover, Netz et al. (2007) examined the effect of acute aerobic exercise (walking on treadmill) on cognitive flexibility in the middle-aged adults (age 50-64) with three different exercise conditions: moderate exercise (60% of HR), moderately-intense (70% of HR), and a control group/no exercise. Cognitive flexibility was assessed via the Alternate Uses test (Guilford, Christensen, Merrifield, & Wilson, 1978). Both the moderate and moderately-intense groups showed an improvement in their cognitive flexibility compared to the control group.

Regardless of age, gender, intensity level, or the length of exercise treatment, these studies reported above show that exercise can have a positive impact on cognitive function. These studies were carried out with different timeframes of intervention (exercise) ranging from as short as one single bout, to 6 weeks, and up to 12 weeks. As a general observation, an assumption can be made that it could be due to the nature of the physical condition of the age groups, specifically in the young children and aging population. Low insensitive, higher frequency and over longer length of intervention is usually ideal or considered safer for elderly or population with physical concerns. As mentioned above, a limited number of studies have focused on young adults, specifically of the college age. That being the case, the present study was designed to examine the effect of moderate aerobic exercise on the cognitive flexibility of college-aged young adults.

Methods

Participants

A total of 32 full-time, undergraduate students enrolled at a university in central Taiwan and who exercised less than 50 minutes per week in the past 3 months or more, were recruited to participate in this study. The participants were randomly assigned to either an experimental or a control group with an equal number of male (n = 8) and female (n = 8) students in each group. The mean age of participants was 21.78, SD = 1.88. All participants were asked to fill out a health condition safety check form and a demographic background form prior to the beginning of the study. Any participant with varsity sports background, extensive exercise experience, or physical limitations was excluded from the study.

Testing Instrument

The Stroop Color and Word Test (Golden, 1978), developed to measure selective attention, cognitive flexibility, and information processing speed was used in the present study. Cognitive flexibility refers to the brain's ability to transition from thinking about one concept to another (Scott, 1962). The Stroop effect is a demonstration of interference in the reaction time of a task (Golden, 1978).

The test consists of a Word Page with color words in Chinese printed in black ink, a Color Page with 'Xs' printed in color, and a Color-Word Page with words from the first page printed in colors from the second page (the color and the word do not match). This test is primarily reserved for individuals between the ages of 15 and 90. The participant was required to go down each sheet reading words or naming the colors as quickly as possible within a time limit.

Procedure

All participants were briefly introduced to the study and signed the informed consent form prior to entering the study. Each participant attended two test sessions. For the control group, the participants were tested at times scheduled with the investigator. For the group engaged in aerobic exercise, participants were tested before the first exercise session and after the last exercise session. Each participant was tested individually in a quiet room. The time span between the two test sessions was the same for both groups. The investigator tested participants of the experimental group based on their exercise schedules. The exercised group was required to participate in an aerobic exercise for 50 minutes per session at an intensity of 50%-70% of their maximum heart rate, three (3) times a week for four (4) weeks and not to engage in any other exercise or physical activity during the four weeks of the experiment. After each exercise session, the participants were asked to measure their heart rate for 10 seconds and report it to the investigator to make sure the exercise intensity was met. This maximum rate is based on the person’s age. The estimated maximum age-related heart rate would be calculated as 220 - age = # beats per minute (bpm). Those in the control group, however, were not required to participate in any exercise during the same time period and maintained their current inactive lifestyle. The procedure was primarily based on Stroth’s study (2009), in which the intervention was performed 3 times in 30-minute running sessions for 6 weeks. Based on the reviews from the previous studies (as cited in Strong et al., 2005), the authors believed a longer session (50 minutes) with a shorter length (4 weeks) will have a better impact on cognitive flexibility.

Aerobic exercise program & the setting

Participants in the exercise group (experiment) were required to participate in the aerobic exercise program, which consisted of 12 50-minute sessions, scheduled three sessions a week for four weeks and was led by a certified trainer specializing in aerobic group exercise. The exercise sessions were comprised of a 10-minute warm-up period with low intensity movement and dynamic stretching, 30 min of low to moderate intensity aerobic exercise, and finally a 10-minute cool-down period. The location of the exercise was held at one of the gym classrooms at the university. Participants were expected to attend all exercise sessions for four weeks (12 times). If the participant did not meet the expectation, he/she was excluded from the study.

Statistical Analysis

The study focuses on whether the students’ attention was improved if they participated in aerobic exercise regularly. A 2 x 2 (Group x Test) mixed factorial ANOVA was used on the test to analyze the differences in selective attention and information processing speed between the two groups. It contained two levels of the between-subject factor “group” (exercise vs. non-exercise) and two levels of the within-subject factor “test” (pre- and post-intervention). Statistical significance was set at $p < .05$. Due to only two levels of each independent variable, a follow-up analysis of a significant interaction was examined by analyzing the mean directly.

Results

A total of 32 participants accomplished the study. The Stroop and Color and Word Test were administered before and after the aerobic exercise program. Therefore, a 2 x 2 (Group x Test) mixed factorial ANOVA using SPSS GLM was used to assess whether the score of interference could be predicted from group (exercise, control) and test (pre, post) and the interaction between group and test. Preliminary data screening was done to assess whether the assumptions for ANOVA were seriously violated. The Mauchly’s test of Sphericity indicated no significant violation of the assumption of homogeneity of variance/covariance matrices across groups. As predicted, there was a statistically significant interaction between group and test, F (1, 30) = 20.07, $p < .05$. The corresponding effect size estimate (η^2 = .40) indicated a strong effect (seen in Table 1). Table 2 indicated the difference of interference scores between pre-test and post-test as a whole while Figure 1 indicated that the exercised group in post-test had the lowest mean of interference scores than the control group.

Table 1

The F Tests the Effect of between and within Subjects

Source	*SS*	*df*	*MS*	*F*	*p*	η^2
Between						
Group	189.06	1	189.06	.32	.57	.01
Error	17547.94	30	584.93			
Within						
Test * Group	1260.25	1	1260.25	20.07	.00**	.40
Error(Test)	1884.19	30	62.81			

Note. $*p < .05$. $** \ p < .01$. $***p < .001$

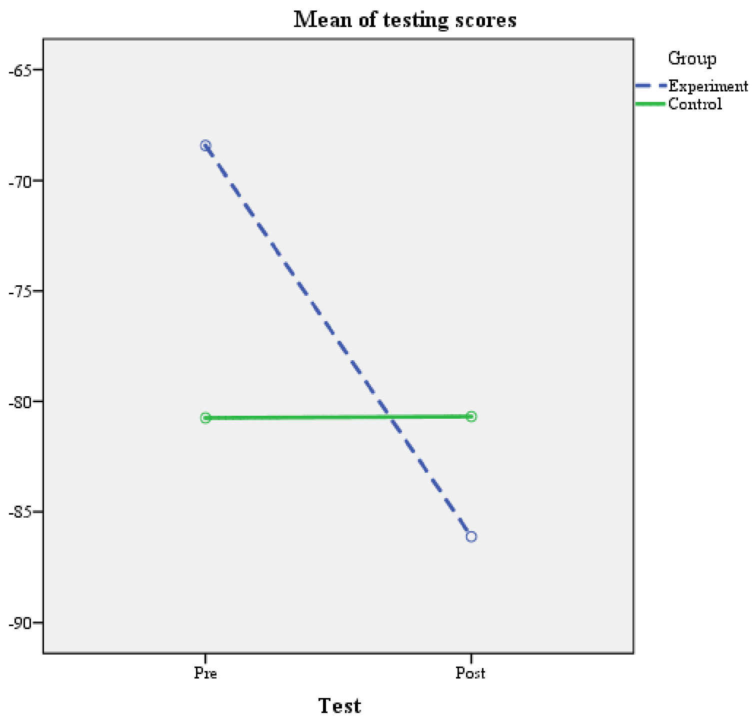

Figure 1 Shown the mean scores of pre and posttests via groups

Table 2
Pairwise Comparisons of Tests and Group

Tests	*M*±*SE*	*MD**	*SE*	*p*
pretest	-74.60±3.37			
		8.81	1.98	.00*
posttest	-83.41±3.00			
Group				
Exercised	-77.28±4.28			
		3.44	6.05	.58
Non-exercise	-80.72±4.28			

Note. Values are mean ±SE MD = Mean Difference*

Discussion

The main purpose of this study is to investigate the effect of aerobic exercise on cognitive functioning performance in young adults. The cognition test to measure the effects of exercise was the Stroop test which is a measure of cognitive flexibility or executive function. The prefrontal cortex is the anterior part of the frontal lobe of the brain (Bloom, Beal, & Kupfer, 2002) and is a region that stores short-term memory. Due to the insufficiency of literature on the age group, prior theories established in animal (Van Praag, Shubert, Zhao, & Gage., 2005; Vaynman, Ying, & Gomex-Pinilla, 2004) and other age groups such as preschoolers (Palmer et al., 2013), school-aged children (Davis et al., 2007), mid-aged adults (Harveson et al., 2016; Netz et al., 2007), and the elderly (Bula, 2016; Heise & Kovacevic, 2016; Kamijo et al., 2007; Netz, Argov, & Inbar, 2009; Phillips et al., 2016) are utilized in the present study.

Researchers (e.g., Barnes, Yaffe, Satariano, & Tager, 2003; Bula, 2016;

Heise & Kovacevic, 2016; Kamijo et al., 2007; Kramer, Colcombe, McAuley, Scalf, & Erickson, 2005; Kramer & Erickson, 2007; Van Boxtel et al., 1997) in the study of aging humans indicated that endurance exercise could prevent cognitive decline, especially in executive planning and working memory. During the aerobic exercise, the blood brings oxygen into the areas of the brain and fuel to fulfill the body's energy demand crucial for task performance (Kramer et al., 1999). In Kamijo's study (2007), a walking program was implemented, which consisted of 40 minutes of walking twice a week for 12 weeks. 26 sedentary older adults performed a response compatibility task before and after the walking intervention. The reaction time and error rate were measured and the results indicated that cognitive processing speed began to improve through the 12-week aerobic exercise program. Researchers said that walking types of exercise increased the rate of oxygen consumption in the elderly and that was associated with an increase in cognitive performance in tests of executive functioning, such as reaction speed and memory (Bula, 2016; Heise & Kovacevic, 2016; Kramer et al., 1999).

In the present study, the exercise group had a lower interference score than the control group. As such, the exercise group had better attention/concentration ability than their counterparts after the 4-week aerobic exercise intervention. This is consistent with published studies that demonstrate the significant effects of exercise on executive function as illustrated above (Guiney & Machado, 2013; Hillman et al., 2005). As a result, the 4-week time span, of exercise intervention can be considered sufficient to improve cognitive flexibility in young adults.

Regarding the exercise intensity, the exercise intensity designed in the study was set at moderate intensity. According to the Center for Disease

Control and Prevention (CDC) in the United States of America, a total of 2 hours and 30 minutes (150 minutes) of moderate-intensity aerobic activity is recommended every week for adults from 18-64 years. Examples of moderate intensity are brisk walking, water aerobics, or riding a bike on level ground or with a few hills. An indication of reaching moderate intensity is that during the exercises, the person is able to talk or chat with workout partners but not sing a song.

In terms of cognitive flexibility, our results align with previous studies. Masley et al. (2009) measured memory, mental speed, reaction time, attention, and cognitive flexibility on 91 healthy adults over a 10-week period and found that moderate aerobic exercise (3-4 days/week) is associated with cognitive flexibility in healthy adults. The present study found that the exercise group had a better attention/concentration score in a cognitive test than the inactive group. This confirms with what Masley et al. suggested in their study and suggests that exercise at a level of moderate intensity with a frequency of 3-4 days a week has positive effects on cognitive flexibility in young adults over a length of four-week routine exercise. The results of the present study also support the work of previous studies demonstrating that aerobic exercise and greater levels of aerobic fitness are associated with cognitive improvement. All these evidences combined indicates that aerobic exercise has a positive influence on cognitive functioning in any age and also suggests that greater aerobic exercise intensity results in significant improved cognitive functioning especially on working memory and executive functioning.

Conclusion

In conclusion, the result of this study suggests that a 4-week moderate aerobic exercise for 50 minutes (including warm-up and cool down) with the frequency of 3 times a week can have positive effects on cognitive functioning performance for young adults. Based on the findings, regular aerobic exercise opportunities should be encouraged not only for physical health benefits but also for mental benefits as well, specifically cognitive flexibility.

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