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Research article

THE RELATIONSHIP BETWEEN WORKING MEMORY CAPACITY AND PHYSICAL ACTIVITY RATES IN YOUNG ADULTS

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ABSTRACT
This study examined the relationship between physical activity and cognitive function in younger adults. It was hypothesized that there would be a relationship between the exercise rates of adults (aged 19-30) and working memory capacity. Participants were 42 male and female college students who were divided into groups based on self-reported physical activity level. The participants in one group (n = 23) met the physical activity requirements specified by the Center for Disease Control and Prevention (CDC), and participants in the other group (n = 19) did not, and therefore acted as the control. A reading span task was used to assess the participant's working memory capacity. Analysis of variance results demonstrated that exercise was associated with enhanced memory ($F = 9.06$, $p = 0.005$, $\eta = 0.21$). Differences in working memory capacity as a function of gender and department were not statistically significant, nor were any interactions between these variables. This finding lends support to the hypothesis that exercise is related to working memory capacity in younger adults.

KEY WORDS: Physical activity, cognitive function, recall.

INTRODUCTION

Researchers have explored the benefits of physical fitness on cognitive function over the past several decades. Early studies by Spirduso (1975) showed that older athletes had shorter response times on several different types of reaction time tasks than sedentary adults. Since then, researchers from several different fields have investigated this relationship using diverse methods, populations, and types of cognitive measures. For instance, neuroscientists focused on the mechanisms by which exercise may have an impact on cognitive functioning. Some researchers suggested that exercise may provide cognitive benefits because it increases cerebral blood flow, which brings important nutrients such as glucose and oxygen to the brain (Chodzko-Zajko, 1991; Madden et al., 1989). Researchers using animal models have suggested that exercise may have an influence on cognitive function because it results in changes to brain structures such as the cerebral cortex (Black et al., 1990) and the hippocampus (van Praag et al., 1999).

Overall, studies with human models have supported the hypothesis that exercise has an effect on cognitive function. In a rigorous and systematic meta-analysis of the effect of physical activity on cognitive function in humans (Etnier et al., 1997), the mean effect size (ES) was 0.25 (SD = 0.69, n = 1260, $p < 0.05$), an analysis that included a total of 134 studies of acute and chronic exercise. As is the case with Spirduso's (1975) study, much of the research in this area focused on older adults, a population that is of particular interest to researchers because older adults are more susceptible to cognitive decline due in part to age-related deterioration in brain function (Kramer et al., 2000).

Several researchers have suggested that in older adults, aerobic fitness has a larger impact on tasks that require effortful processing than tasks that are executed using automatic processing (Chodzko-Zajko, 1991; Chodzko-Zajko and Moore, 1994). However, there is inconsistent support for this hypothesis. For example, one study reported a stronger relationship between fitness and performance on effortful Stroop interference conditions than performance on tasks that are more automatic, such as simple color and word naming (Schuler et al., 1993). This finding has not been consistently reported as other researchers have failed to find this differential effect in older adults using different cognitive measures (Hill et al., 1993; Blumenthal et al., 1991).

To explain this discrepancy, Kramer et al. (1999; 2000) suggested that in older adults, aerobic fitness would be related to selective improvements in executive control processes such as coordination, planning, and working memory. This hypothesis was based on literature that showed the part of the brain responsible for this type of brain activity tends to decline earlier in the aging process (West, 1996). To test this hypothesis, the researchers had sedentary older adults participate in a 6-month aerobic walking program or an anaerobic control group (Kramer et al., 1999). The researchers found that the adults in the walking group performed better than the adults in the control group on a variety of executive control tasks. A follow-up study using neuroimaging techniques showed that aerobically trained older adults had greater activity in the brain areas that are thought to support executive control functions (Colcombe et al., 2004). The hypothesis that fitness would be related to selective improvements in executive control processes was also supported by a review of 18 randomized intervention studies (Colcombe and Kramer, 2003). The authors found that exercise does in fact have the largest effect on executive control processes when compared to the effects on speed, visuospatial, and controlled processes. Overall, the effect of exercise on cognitive performance was 0.5 standard deviations.

There has been a dearth in research that has explored the effect of exercise on executive control processes in younger adults. To date, no published studies were located that have examined the difference between fit and unfit younger adults on a working memory task. The purpose of the present study was to extend the previous research by examining whether the relationship between physical activity and working memory was present in this population. It was hypothesized that exercise rates would have a main effect on working memory capacity.

METHODS

Participants

Participants were 42 undergraduate and graduate students at a public university. The sample consisted of 17 male and 25 female students. The participants ranged in age from 19 to 29, with a mean age of 22.9 (SD = 2.26). To increase the probability of a diverse range of exercise habits, participants were recruited from the physical education department and the psychology department.

Measures

Participants completed a short demographic questionnaire that assessed age, gender, height, and weight. Height and weight measurements were used to compute body mass index (BMI) for each participant using the formula: (weight)/(height^2).

The instrument used to assess physical activity levels was developed by researchers at the Cooper Institute for Aerobics Research. The instrument was designed to assess physical activity habits in the general population. Participants were asked to report moderate or vigorous activities that had been performed regularly in the previous 3 months, and to estimate the amount of that activity. The activities ranged from walking to weight training. Scoring involved assigning metabolic equivalent task (MET) values to each activity, which were placed in a formula that resulted in a MET-hour/week value.

A validation study conducted on this questionnaire showed statistically significant correlations between a maximal physical fitness assessment and portions of the questionnaire (Kohl et al., 1988). Significant predictors of physical fitness included participation in running, walking, and jogging. The multiple correlation coefficient between these variables, participant age, and maximal fitness was $r = 0.65$.

Participants also completed a task that was adapted from Daneman and Carpenter's (1980) reading span task. This task required the participants to read a series of sentences and then recall the last word of each sentence. While this task is designed to assess reading span, it has also been widely used as a measure of working memory capacity (Daneman and Merikle, 1996) because the central executive in working memory is assumed to have both a storage capability and a processing capability. This task reflects both of these components, and is able to

Table 1. Descriptive data for exercise groups. Data are means (±SD).

	n	% Female	Age	BMI	MET h/wk	Working Memory Capacity
Fits Requirement	23	65	22.8 (2.2)	23.6 (3.9)	46.5 (21.2)	4.5 (1.5)
Does Not Fit Requirement	19	52	23.2 (2.3)	25.1 (6.4)	17.1 (14.9)	3.2 (1.0)

identify differences in people's ability to coordinate them. For example, individuals with a small storage capacity who are unable to temporarily store information in their working memory are also unable to integrate new information with previously processed information, and will score lower on the task.

In this task, the participants were asked to read the series of sentences out loud as they were presented individually on 5 X 8 in index cards. The sentences were grouped, and the end of a group was signaled by a blank index card. The number of sentences in each group increased as the task progressed, with 5 sets each of 2, 3, 4, 5, and 6 sentence groups for a total of 100 sentences. Each sentence was between 13 and 16 words, and each ended in a different word.

Before the task started, the participants were informed that they would need to recall the last words from the sentence (in the order that they were presented) after the entire set had been read. The participants were instructed to write down the last word from each sentence on a sheet of paper that was provided to them. If the participants were unable to recall all of the words, they were instructed to recall whatever they could. Reading span was calculated as the last set at which the participant could correctly recall 80% of the words.

Procedure

Information was collected from the participants individually in a private office. Written informed consent was obtained from the participants after the study was explained to them. Participants then filled out a short demographic questionnaire and a paper-and-pencil measure of physical activity. Next, the participants completed the test to measure working memory span. The participants also completed two temporal discounting tasks, but these results were not reported here due to a lack of relevance to the present study.

The participants were categorized into two groups based on their responses on the exercise questionnaire. The Center for Disease Control & Prevention (CDC, 2000) recommends that adults participate in leisure-time physical activity at least 5 times per week for the duration of 30 min, or vigorous physical activity at least 3 times per week for the duration of 20 min. Based on these specifications, 23 of the participants reported that they fit the criteria for the recommended amount of exercise and 19 reported that they did not.

Inferential statistical tests were done using SPSS Version 12.0. Differences in working memory capacity between gender, department, and exercise group were measured using a univariate analysis of variance (ANOVA). Exercise group was the variable of interest, but gender and department were included in the analysis to explore interactions with working memory capacity. The alpha level was set at 0.05 for a difference to be deemed statistically significant.

RESULTS

Descriptive statistics for the entire sample of participants, categorized by exercise group, can be found in Table 1. The exercise groups did not differ significantly with regard to age, gender, or BMI.

Table 2 contains descriptive data for the same variables, with participants grouped by academic department. The psychology and physical education students differed on BMI and MET-hour/week, although the differences only approached statistical significance ($p = 0.06$ and 0.07, respectively).

The results from the univariate ANOVA

Table 2. Descriptive data by academic department. Data are means (±SD).

	n	% Female	Age	BMI	MET h/wk	Working Memory Capacity
Physical Education Students	23	56.5	23.3 (2.2)	22.9 (3.4)	39.0 (24.0)	3.86 (1.46)
Psychology Students	19	63.2	22.6 (2.3)	25.9 (4.0) [a]	26.1 (21.7) [b]	3.95 (1.51)

[a] $p = 0.06$ and [b] $p = 0.07$ compared with physical education students' group.

demonstrated that exercise group had a statistically significant main effect on working memory capacity ($F = 9.06$, $df = 1$, $p = 0.005$, $\eta = 0.210$), whereby participants in the exercise group reported significantly better memory scores. There were no statistically significant differences in working memory capacity as a function of gender or department. None of the interactions tested were statistically significant.

DISCUSSION

The purpose of the present study was to examine the relationship between working memory capacity and level of physical activity participation in a sample of young adults. It was hypothesized that a relationship would exist between these factors, and the present data supported this hypothesis. This result was consistent with previous research on the topic. As is the case with older adults, exercise was related to working memory, a part of cognitive functioning that requires effortful processing. Therefore, it appeared that exercise may also have an impact on this type of processing even before it declines due to aging. Also, just as exercise had an overall small effect on the many different types of cognitive functioning included in the review by Etnier et al. (1997), it had a fairly small effect ($\eta = 0.210$) on working memory in this sample of younger adults.

Several limitations were present in this investigation that could be addressed by future studies. As was discussed by Etnier et al. (1997), smaller effect sizes were found when fitness level was not assessed directly through a measure such as maximal oxygen uptake. Despite evidence for the validity of the self-report instrument used (Kohl et al., 1988), there may be bias in self-report measures in the form of social desirability response set (Gall et al., 2003). Future studies of this relationship could measure fitness directly, in order to more precisely determine the magnitude of the relationship.

Also, as with any quasi-experimental study, statements of directionality in causation cannot be made. Therefore, the results of this study might simply indicate that there are pre-existing cognitive differences that lead certain people to exercise (Etnier et al., 1997). Future research might also focus on this limitation by employing a longitudinal intervention study.

CONCLUSIONS

The present findings supported the hypothesis that exercise is related to an effortful processing task that measured working memory in younger adults. The working memory capacity of individuals who fit recommended exercise requirements differed from those who did not. Working memory capacity did not differ with regard to gender or the academic department from which the participants were recruited.

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KEY POINTS

- The purpose of this study was to examine differences in working memory capacity as a function of exercise rate in younger adults.
- The results showed that there was a difference in working memory capacity between individuals who met the CDC's requirements for physical activity frequency and duration and individuals who did not.
- Similar to older adults, differences in cognitive function as a function of exercise were present in younger individuals.

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