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The Relationship between Physical Exercise and Cognitive Ability(II)

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This study was conducted with 120 subjects in their teens to investigate changes in their cognitive processes after exercise.

The result showed differences between the two test groups in all tasks. Changes in working memory were positiv regardless of sex in the group which exercised than in the one which did not; in other tasks such as the labyrinth test, sequence test, and arithmetic test changes were positive only in the male group.

Therefore it was concluded that a proper amount of exercise can facilitate cognitive processes: working memory, perception, and reasoning and that the effects of exercise can be variable depending on the personal state of the subjects including his attitude toward exercise and depending on the intensity and duration of exercise.

INTRODUCTION

While the physiological effects of exercise have been relatively well examined, little has been investigated about the effects of exercise on cognitive functioning(Tomporowski, P. D., & Ellis, N. R.).

Just as a sequel to the previous study attempted to demonstrate the relationship between physical exercise and cognitive ability, this study aims to determine the effects of exercise on cognition, which can vary according to age, through observing how cognitive processes change in teen-age subjects after exercise.

This study is based on the following three-point hypothesis: (1) since exercise is not mere movement but conscious human behavior which requires information processing of man's everchanging conditions including himself, the effects of exercise on congnitive functioning are significant: (2) the effects of exercise on cardiovascular function stimulate cerebral activity and also retard its recession; (3) therefore physical and mental alertness is stimulated after exercise. This study is particularly concerned about the third point.

METHOD

1. Subjects

In view of the fact that the effects of exercise can be variable according to age, the test was conducted exclusively with young subjects. A total of 120 teenagers were divided into four groups: male and female groups and experimental and control groups with 30 subjects in each. The experimental group (EG) was assigned to a 12 week special exercise program while the control group (CG) was allowed to follow their ordinary life patterns. These groups were pretested after being given sufficient information about the cognitive ability test. Then each group was tested separately 4 times. For the EG 2 tests were administered before exercising and 2 other tests after 30 minutes of exercise and a 10 minute recess. For the CG 4 tests were assigned after 40 minutes of studying or reading in the classroom. The initial test was given on the first day of the program and the rest of the tests were conducted at 3 or 4 weeks intervals.

2. Contents and Measurement

The aim of this study is to examine the relationship between physical exercise and cognitive ability in order to determine the changes in the cognitive processes after specific physical activities. This study attempts to understand human ability to solve cognitive problems before and after exercise and to prove its hypothesis through calculations and comparisons classified by group, sex, and time of test.

The tasks for cognitive ability consisted of a memory test, labyrinth test, sequence test and arithmetic test. In the working memory test 10 items were visually presented. The tests were given in the following order and categories: consonants, concrete words, abstract words, 2-digit numbers and pictures. In the labyrinth test the subjects were asked to find their way through as many routes as possible out of a total of 30 within two minutes. In the logical sequence test 30 questions were given, ranging from easy to difficult and they were to answer as many as possible within two minutes. There were 20 arithmetic problems given to anser within two minutes and 30 seconds.

Mood and heart rate were other variables. Prior to all the other tests the mood of each subject was taken at five different stages. For the EG the pulse was taken before and after exercise to detect any changes.

The test scheme was as follows:

	TR	TE1			TE2			TE3			TE4		
EG	P	X1	E	X2	X1	E	X2	X1	E	X2	X1	E	X2
CG	P	X1	O	X2	X1	O	X2	X1	O	X2	X1	O	X2

TR: Practice before test
P: Preliminary test
TE: Measurement
X1: Test before exercise / activity
X2: Test after exercise / activity
E: 30 minutes' exercise and 10 minutes' recess
O: 40 minutes' reading or other activities

3. Analysis of Results

All the results and measurements were computerized in the SAS statistical program. In order to determine the general tendency of the results the mean and standard deviation of the dependent variables and the frequency distribution were calculated. To determine the changes in dependent variables the analysis of variance(ANOVA) was done and verified. Pearson product-movement correlation coefficient was applied.

RESULTS AND DISCUSSION

In order to determine the changes in cognitive ability in subjects before and after exercise, the cognitive abilities were tested by different factors in categorized tasks: working memory, labyrinth, sequence, and arithmetic.

1. Changes in Working Memory before and after Exercise

Working memory was measured in five different tasks: consonants, concrete words, abstract words, 2-digit numbers, and pictures. However, only the mean memory was analyzed here. The changes in working memory before and after certain specific activities are shown by group and test time in Table 1.

Table 1. Changes in memory test before and after exercise

Group	Exercise			Non-Exercise		
Time	Whole	Male	Female	Whole	Male	Female
1	0.259	0.143	0.367	−0.007	0.047	−0.06
2	0.29	0.367	0.213	0.035	0.233	−0.163
3	−0.176	−0.36	0.008	−0.273	−0.36	−0.187
4	0.22	−0.033	0.407	−0.389	−0.547	−0.215

As the ANOVA of the results in Table 1. shows, differences are significant by sex($F=4.15$, $P=0.044$); by group($F=20.16$, $P=0.0001$); by test time($F=8.56$, $P=0.0001$). It was also demonstrated that changes were significantly positive in the female group than in the male one and in the exercise group than in the non-exercise one. The follow-up survey of differences by group reveals that working memory changes more positively in the subjects who exercised than in those who did other activities such as reading or studying. The changes were significant in all the tests but in the third.

The interaction between group and test time was significant($F=3.09$, $P=0.027$); the interaction between sex and test time was also significant($F=4.62$, $P=0.003$); but the interaction between group and sex was not significant ($F=1.86$, $P=0.175$). The fact that no interaction occurred between group and sex indicates that in working memory changes occur in both sexes. An interaction between sex and test time occurred owing to the significant changes that occurred in the male group in the second test.

2. Changes in the Labyrinth Test before and after Exercise

In finding their way through as many routes as possible in the labyrinth test within the specified time, differences were found before and after exercise. The results are shown in the following table.

Table 2. Changes in the labyrinth test before and after exercise

Group	Exercise			Non-Exercise		
Time	Whole	Male	Female	Whole	Male	Female
1	2.069	2.607	1.567	0.287	−1.4	1.967
2	1.933	1.833	2.033	1.733	1.467	2
3	3.233	3.633	2.833	1.867	1.833	1.9
4	0.233	−0.767	1.233	−0.491	−1.6	0.741

AS the ANOVA in Table 2. reveals, differences are significant by test time($F=19.48$, $P=0.0001$); by group($F=17.37$, $P=0.0001$); the interaction between group and sex is also significant($F=7.78$, $P=0.006$). The significant changes caused by test time are not very important because they varied owing to the types and conditions of the tests. More positive changes happened in the groups which exercised than in those which did some other activity. In the first and third test the effects of exercise were positive in labyrinth tracking.

The interaction between group and sex occurred because the female exercise group did not have better scores than the female non-exercise group while the male exercise group revelaed significantly better scores. This indicates that the more positive effects of exercise had an impact on the male subjects. Therfore it may be inferred that the positive desire of men for exercise stimulated mental functioning in the course of maze tracking.

3. Changes in the Sequence Test before and after Exercise

In tracking logical sequence in regard to what comes next, score changes were found before and after exercise. The results are as follows:

Table 3. Changes in labyrinth test before and after exercise

Group	Exercise			Non-Exercise		
Time	Whole	Male	Female	Whole	Male	Female
1	1.259	3.107	−0.467	0.119	−0.567	0.828
2	0.183	0	0.367	0.533	0.667	0.4
3	−2.35	−2.667	−2.033	−2.8	−3.367	−2.233
4	2.717	2.5	2.933	2.439	1.9	−3.037

The analysis of variance of the results in Table 3. shows that some significant changes were caused by test time($F=73.93$, $P=0.0001$); no significant changes by sex($F=0.20$, $P=0.665$); again no significant changes by group($F=2.10$, $P=0.149$); but in the interaction between group and sex changes were significant($F=6.26$, $P=0.014$).

The significant changes caused by test time are not very important because they were variable depending on the environmental conditions. In the group which exercised the differences were greater after exercise than in the group which did other activities. The effects of exercise were greater particularly in the first of the sequence tests.

The interaction between group and sex was significant because in the male exercise group changes showed more positive than in the male non-exercise group, but as for the female subjects the difference between the exercise and non-exercise group was not significant. This clearly indecated that the effects of exercise were more positive on the male subjects.

4. Score Changes in the Arithmetic Test before and after Exercise

Table 4. demonstrates the score changes before and after exercise; the scores were examined by group and test time.

Table 4. Changes in arithmetic test before and after exercise

Group	Exercise			Non-Exercise		
Time	Whole	Male	Female	Whole	Male	Female
1	2.0	1.857	2.133	−0.167	−2.667	2.333
2	0.1	0.4	−0.2	0.661	1.2	0.103
3	0.833	1.567	0.1	1.383	1.467	1.3
4	1.4	1.433	1.367	0.719	0.533	0.926

According to the analysis of variance of the results in Table 4. there were no significant changes by test time($F=1.76$, $P=0.155$) and by sex($F=0.82$, $P=0.367$). However the difference was not very great, but fairly significant depending on the group($F=3.82$, $P=0.053$). The interaction between group and sex($F=6.26$, $P=0.014$) and between group and test time($F=7.73$, $P=0.0001$) were also significant.

The follow-up analysis indicated that in the first test there were more effects on the exercise group than on the non-exercise one, but in the rest of the tests the difference was not significant. In the interaction between group and sex the score difference was more positive in the male exercise group than in the male non-exercise group. But the score difference was not significant in the female groups regardless of whether it was an exercise or non-exercise group. This demonstrates that the effects of exercise were more positive on the male subjects than the female subjects.

5. Mood and Cognitive Ability before and after Exercise

What changes happened in the subjects after exercise were investigated by group and test time.

Tabel 5. Changes in mood before and after exercise

Group	Exercise			Non-Exercise		
Time	Whole	Male	Female	Whole	Male	Female
1	0.103	0.25	−0.033	0.017	0.033	0
2	0.017	0.133	−0.1	0.033	0.067	0
3	0.5	0.1	0.9	0.267	−0.067	0.6
4	0.617	0.1	0.233	0.14	−0.067	0.37

The ANOVA of the changes in mood demonstrates the following results: by test time($F=3.13$, $P=0.026$); by sex($F=5.12$, $P=0.026$); by group($F=0.89$, $P=0.347$). The differences were significant between sexes, but not between

groups. As far as interaction is concerned, differences were significant only between sex and test time($F=6.06$, $P=0.0005$) and not between group and sex ($F=0.36$, $P=0.550$) and between group and test time($F=0.77$, $P=0.513$). According to the follow-up analysis, the male subject were in better mood after activities than the female ones in the first and second test, while the female subjects were in better mood in the third and fourth test.

How the factors found in the changes of mood and the changes in cognitive ability are mutually related are determined and analysed in Table 6.

Table 6. Correlationships between mood and the factors of cognitive ability

	Working memory	Labyrinth	Sequence	Arithmetic
Mood	0.002	−0.020	−0.026	−0.033

As Table III−6 reveals, no correlationship is found among the pre- and post-exercise changes in mood and in cognitive ability. The result indicates that the changes of mood had no effect on the changes in cognitive ability and that the teenage subjects could control themselves despite their mood.

6. Heart Rate Change in Exercise Group

The pulse of each subject was taken and recorded before and after exercise and the changes were studied in Table 7.

Table 7. Heart rate change in experimental group

Group	Exercise		
Time	Whole	Male	Female
1	9.617	10.333	8.9
2	10.87	13.333	8.40
3	16.60	19.20	14
4	14.017	17.167	10.867

Table 7. demonstrates that the average heart rate increases after exercise by 10 beats per minute and the rate is higher in males than in females. In the third and fourth test the increasing rate is higher than in the first and second test. The ANOVA shows that the difference was significant by sex ($F=5.24$, $P=0.026$) and by test time($F=3.95$, $P=0.009$), but the interaction between sex and test time was not significant ($F=0.44$, $P=0.723$). The results

indicate that the subjects exercised so intensely that they did not regain the state they had before exercise even after a 10 minute recess. Particularly in the third test the pulse was taken while the subjects were still in a state of excitement from the exercise. It is clear that the male subjects were put through more intense exercises than the females.

CONCLUSION

The conclusion is that a proper amount of exercise can facilitate congnitive processes: working memory, perception, and reasoning, and that the positive effects of exercise can vary depending on the personal state of the subjects including his attitude toward exercise. This is based on the hypothesis that physical and mental alertness is stimulated after exercise and the function of memory, perception, and reasoning improve. If this conclusion is accepted, a moderate amount of exercise should be prescribed so as not to cause fatique, while precautions should be taken not to evoke an adverse reaction from those who do not duly appreciate exercise.

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