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The Acute Effects of Moderate Intensity Aerobic Exercise on Short-Term Memory in College Students

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Abstract **Purpose:** To analyze the acute effects that exercise has on short-term memory. **Methods:** Subjects (n=24) were Liberty University students ages 18-24 that were classified as low-risk by ACSM standards. Testing was performed on two, nonconsecutive days. The first day, subjects performed a 1.5-mile run at their own pace, from which VO_{2max} was calculated. The second day, subjects were administered three versions of a memory test comprised of a modified Reys Auditory Verbal Learning Test (RAVLT) and the Immediate Memory (IMMED) and Concentration (CONC) portions of the Sport Concussion Assessment Tool Version 5 (SCAT5). The first version was administered at the beginning of the testing session. The second was given immediately after the subject exercised for 10 minutes at 50% of their pre-determined VO_{2max}. The third was administered 30 minutes after exercise. Prior to each memory test, blood oxygen (O2) levels, heart rate (HR), and blood pressure (BP) were checked. **Results:** Results showed no significant relationship between changes in any of the physiological factors and changes in scores for the RAVLT and CONC tests. However, results did show a trend between changes in HR and changes in IMMED test scores, although this was not statistically significant. **Conclusion:** Moderate intensity aerobic exercise does not appear to affect short-term auditory-verbal memory, immediate memory, or concentration performance. However, aerobic exercise may affect immediate memory if different exercise parameters are used. When considering the fatigue factor and excess post-exercise oxygen consumption (EPOC), the results may indicate that aerobic exercise at a higher intensity or longer duration could improve immediate memory performance. The results of this study could assist researchers in determining what exercise intensity and duration significantly benefits immediate memory.

Keywords Cognition, Exercise, Memory, Physiology

1. Introduction

It has been proposed that certain physiological changes that occur in response to exercise also contribute to memory retention [10]. Some physiological variations result from a single bout of exercise, while others develop over time. Research has yielded both acute and chronic physiological changes benefit aspects of cognitive function. This study analyzes the effects that a single bout of aerobic exercise has on three aspects of cognitive performance: short-term auditory verbal memory, immediate memory, and concentration.

2. Purpose

The purpose of this study is to determine whether submaximal aerobic exercise yields immediate cognitive benefits. Many college students spend hours doing school work and studying, but research shows that 40-50% of college students are inactive [12]. Surveys indicate the reason behind inactivity is not usually indifference. Many inactive people say that they are not opposed to being more active, but admit that they lack time or motivation [8]. Since college students often have a large workload and are short on time, they do not always prioritize physical activity even though it has shown to lead to improved quality of life and health. [15]. Students feel that if they regularly exercise, they will not have time to finish their assignments or study enough for their exams. However, both human and non-human animal studies have shown that aspects of cognition and performance can be improved by aerobic exercise. Exercise might not only benefit physical health, but might also enhance academic performance [11]. If physical activity can improve students' cognition and protect brain function, they may be more motivated to make exercise a part of their routine [7]. Exercise may be viewed in a more productive light if it not only improves quality of life and health, but also enhances cognitive performance.

It is known that exercise causes certain physiological changes to occur, including changes to the respiratory, cardiovascular, endocrine, nervous, and circulatory systems.

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It has been proposed that some of these physiological changes also contribute to cognitive function. One way that exercise can benefit the body is by affecting synaptic pathways. Exercise directly affects synaptic structure, potentiates synaptic strength, and strengthens the underlying systems that support synaptic plasticity such as neurogenesis, metabolism, and vascular function. Over time, these changes increase synaptic plasticity [6]. If synaptic function is improved, nerve impulses can travel quicker to the brain. This allows for enhanced brain function. Exercise also affects neurotransmitter and protein activity. For example, exercise elevates levels of brain-derived neurotrophic factor (BDNF). BDNF is a protein that plays a major role in cognitive function by affecting the mechanisms governing memory formation and storage dynamics.

Brain structures affected by exercise include the prefrontal, frontal and parietal cortices and the hippocampus. The prefrontal cortex is associated with functions such as planning and decision-making. The frontal cortex is involved with problem solving, memory, and judgment. The parietal cortex is responsible for causing sensation and perception. Aerobic exercise has been found to improve functioning of the prefrontal, frontal and parietal cortices [25]. In addition to improving the efficiency of certain brain structures, aerobic training has shown significantly affect regional brain volume. Aerobic training has shown to increase the volume of gray matter in the lateral prefrontal anterior cingulate and lateral temporal cortices and to increase volume of anterior white matter. Exercise also increases the size of the hippocampus, a part of the brain associated with long-term memory [9].

Although there are many physiological benefits of exercise, it may also be that the fatigue factor associated with exercise outweighs these acute benefits. If this is the case, people could be less attentive and exhibit poorer retention and concentration following an exercise bout. For this reason, this study analyzes the impact that submaximal aerobic exercise has on short-term memory at three different times: before exercise, immediately after exercise, and thirty minutes after exercise.

The potential effect that the acute physiological changes of exercise could have on cognitive function is relatively unresearched. Research shows that regular aerobic exercise can positively impact cognitive function over time, but the acute effects of a single exercise bout should be further investigated. Therefore, the purpose of this study was to examine the effects of a single bout of exercise on short-term memory. Specifically, this study examines the effects of a single bout of moderate intensity aerobic exercise on short-term auditory-verbal memory, immediate memory, and concentration, while considering the fatigue factor. Results could show that a single bout of moderate intensity aerobic exercise has a delayed effect on cognitive function, causing an initial decrease in performance followed by a greater increase in performance thirty minutes post-exercise.

3. Methods

3.1. Subjects

Twenty-four Liberty University students ages 18-24 were used as subjects. Of these 24 participants, 12 were females and 12 were males. Potential subjects were recruited by word of mouth and were risk stratified according to the American College of Sports Medicine guidelines [1]. Only those who were classified as “low” risk were permitted to continue in the study. Each subject who qualified was informed of the study’s procedures and required to complete an informed consent form before beginning testing. This study was reviewed and approved by the institutional review board for human subjects’ research before testing commenced.

3.2. Experimental Design

A single-group repeated measures cross-over design with counterbalanced trial order was used. Testing occurred on two, non-consecutive days. Subjects were not permitted to exercise within three hours of testing on a given day. The first day, subjects performed the 1.5-mile run test, from which VO_{2max} was calculated. The 1.5-mile run test was performed on the LaHaye Recreation Center’s indoor track at Liberty University. Subjects were not permitted to start the run at the same time, nor were they be permitted to run together.

The second day, subjects came to the Human Performance Lab at Liberty University and went through a three-stage protocol during which they were given three versions of a similar memory test. Each version of the memory test followed the same format but utilized different words and numbers. The memory test was comprised of three sections: a modified Reys Auditory Verbal Learning Test (RAVLT), the Sport Concussion Assessment Tool Version 5 (SCAT5) Immediate Memory Test, and the SCAT5 Concentration Test. Immediately before the administration of each version of the memory test, heart rate, blood pressure, and blood oxygen saturation were checked. During Stage 1, subjects took Version A of the memory test. After completing Version A of the memory test, subjects continued with Stage 2. Stage 2 required subjects to exercise on a treadmill for 10 minutes at 50% of their VO_{2max} after a 2-3-minute warm-up.

Immediately after exercise was finished, heart rate, blood pressure, and blood oxygen saturation were checked. Subjects then took Version B of the memory test. After finishing Stage 2, subjects began Stage 3. Stage 3 started with a 30-minute rest period during which subjects were not permitted to use electronics or participate in any mentally- or physically-demanding activities. After the thirty minutes were up, heart rate, blood pressure, and blood oxygen saturation were checked. Subjects then took Version C of the memory test. The memory test scores and the values for heart rate, blood pressure, and blood oxygen saturation were examined for possible correlation.

3.3. Procedures

3.3.1. VO_{2max}

VO_{2max} was determined for each subject based on the amount of time it took to run 1.5 miles. The 1.5-mile run test was performed on the first day of testing. The following formula was used to calculate VO_{2max} from the 1.5-mile run time:

$$VO_{2max}\ (\text{ml/kg/min.}) = 3.5 + 483/\text{time in min.} \quad (1)$$

3.3.2. Exercise Protocol

Subjects' 50% VO_{2max} value was converted to METs to determine the exercise intensity for each subject for the second day of testing. The following formula was used to convert VO_2 to METs:

$$\text{METs} = VO_2/3.5 \quad (2)$$

The calculated METs value was rounded to the nearest treadmill setting. A Trackmaster TMX428 treadmill was used for the exercise protocol on the second day of testing.

3.3.3. HR and O_2

Prior to the first and third measurements, subjects were required to relax in a seated position for 5 minutes with the left arm supported at the level of the heart. The second measurement was taken immediately following the exercise protocol. An oxygen finger sensor was used to check heart rate and blood oxygen saturation.

List I	List II	List III
Curtain [*Gordijn*]	Rabbit [*Konijn*]	Soldier [*Soldaat*]
Bird [*Vogel*]	Shoelace [*Veter*]	Watering can [*Gieter*]
Pencil [*Potlood*]	Paper [*Papier*]	Balloon [*Ballon*]
Glasses [*Bril*]	Kitchen [*Keuken*]	Pipe [*Pijp*]
Shop [*Winkel*]	Ship [*Schip*]	Toddler [*Kleuter*]
Sponge [*Spons*]	Ball [*Bal*]	Wind [*Wind*]
River [*Rivier*]	Fairy-tale [*Sprookje*]	Paint [*Verf*]
Colour [*Kleur*]	Fruit [*Fruit*]	Tower [*Toren*]
Flute [*Fluit*]	Post [*Post*]	Chain [*Ketting*]
Plant [*Plant*]	Face [*Gezicht*]	Foot [*Voet*]
Coffee [*Koffie*]	Rubbish [*Rommel*]	Shed/barn [*Schuur*]
Chair [*Stoel*]	Trousers [*Broek*]	Cat/puss [*Poes*]
Drum [*Trommel*]	Tent [*Tent*]	Mirror [*Spiegel*]
Shoe [*Schoen*]	Doorstep/sidewalk [*Stoep*]	Rose [*Roos*]
Air/sky [*Lucht*]	Lamp [*Lamp*]	Lip [*Lip*]

Figure 1. RAVLT Word List

3.3.4. SBP and DBP

Systolic and diastolic blood pressure (SBP and DBP, respectively) were measured immediately before each memory test. Prior to the first and third measurements, subjects were required to relax in a seated position for 5 minutes with the right arm supported at the level of the heart. The second measurement was taken immediately following the exercise protocol. An Hg column sphygmomanometer and a Sprague-Rappaport stethoscope were used to measure blood pressure.

3.4. Memory Tests

Each version of the memory test followed the same format, but with different prompts. The basic format of each memory test consisted of three sections: a modified Reys Auditory Verbal Learning Test (RAVLT) [3], the Sport Concussion Assessment Tool Version 5 (SCAT5) Immediate Memory Test, and the SCAT5 Concentration Test [19]. The RAVLT was designed to test short-term auditory-verbal memory. During the modified RAVLT, subjects listened to a reading of 15 words lasting for 20 seconds. The word list was read twice in English. Subjects then had one minute to write down as many words as they could remember from the reading.

The second and third parts of the memory test came from the cognitive screening section of the SCAT5. The second part of the memory test was the section of the SCAT5 designed to test immediate memory (IMMED). The third part was the portion of the SCAT5 designed to test concentration (CONC). Both sections of the SCAT5 were administered according to their original format. All memory testing was administered in a quiet environment.

3.5. Statistical Analysis

A bivariate correlation was run using SPSS software to analyze the relationships between the delta values of the physiological factors and the delta values of the test scores. Significant relationships were found across all three time periods between changes in HR and changes in IMMED test scores. The Pearson correlation coefficients indicated the type of relationship between each case of ΔHR versus ΔIMMED was inverse. The criterion for significance was $\alpha \leq$

0.05, with a Bonferroni adjustment for post hoc analysis to determine group differences. To further address the relationship seen with the bivariate correlation between changes in HR and changes in IMMED test scores, a dependent t-test was run. The dependent t-test compared each case of ΔHR and each case of ΔIMMED. Lastly, a repeated measures ANOVA was used to analyze the trend revealed by the dependent t-test between changes in HR and changes in IMMED scores.

IMMEDIATE MEMORY

The Immediate Memory component can be completed using the traditional 5-word per trial list or optionally using 10-words per trial to minimise any ceiling effect. All 3 trials must be administered irrespective of the number correct on the first trial. Administer at the rate of one word per second.

Please choose EITHER the 5 or 10 word list groups and circle the specific word list chosen for this test.

I am going to test your memory. I will read you a list of words and when I am done, repeat back as many words as you can remember, in any order. For Trials 2 & 3: I am going to repeat the same list again. Repeat back as many words as you can remember in any order, even if you said the word before.

List	Alternate 5 word lists					Score (of 5) Trial 1	Trial 2	Trial 3
A	Finger	Penny	Blanket	Lemon	Insect			
B	Candle	Paper	Sugar	Sandwich	Wagon			
C	Baby	Monkey	Perfume	Sunset	Iron			
D	Elbow	Apple	Carpet	Saddle	Bubble			
E	Jacket	Arrow	Pepper	Cotton	Movie			
F	Dollar	Honey	Mirror	Saddle	Anchor			
					Immediate Memory Score	of 15		
					Time that last trial was completed			

Figure 2. SCAT 5 Immediate Memory Test

CONCENTRATION

DIGITS BACKWARDS

Please circle the Digit list chosen (A, B, C, D, E, F). Administer at the rate of one digit per second reading DOWN the selected column.

I am going to read a string of numbers and when I am done, you repeat them back to me in reverse order of how I read them to you. For example, if I say 7-1-9, you would say 9-1-7.

Concentration Number Lists (circle one)					
List A	List B	List C			
4-9-3	5-2-6	1-4-2	Y	N	0
6-2-9	4-1-5	6-5-8	Y	N	1
3-8-1-4	1-7-9-5	6-8-3-1	Y	N	0
3-2-7-9	4-9-6-8	3-4-8-1	Y	N	1
6-2-9-7-1	4-8-5-2-7	4-9-1-5-3	Y	N	0
1-5-2-8-6	6-1-8-4-3	6-8-2-5-1	Y	N	1
7-1-8-4-6-2	8-3-1-9-6-4	3-7-6-5-1-9	Y	N	0
5-3-9-1-4-8	7-2-4-8-5-6	9-2-6-5-1-4	Y	N	1
List D	List E	List F			
7-8-2	3-8-2	2-7-1	Y	N	0
9-2-6	5-1-8	4-7-9	Y	N	1
4-1-8-3	2-7-9-3	1-6-8-3	Y	N	0
9-7-2-3	2-1-6-9	3-9-2-4	Y	N	1
1-7-9-2-6	4-1-8-6-9	2-4-7-5-8	Y	N	0
4-1-7-5-2	9-4-1-7-5	8-3-9-6-4	Y	N	1
2-6-4-8-1-7	6-9-7-3-8-2	5-8-6-2-4-9	Y	N	0
8-4-1-9-3-5	4-2-7-9-3-8	3-1-7-8-2-6	Y	N	1
		Digits Score:			of 4

MONTHS IN REVERSE ORDER

Now tell me the months of the year in reverse order. Start with the last month and go backward. So you'll say December, November. Go ahead.

Dec - Nov - Oct - Sept - Aug - Jul - Jun - May - Apr - Mar - Feb - Jan	0 1
Months Score	of 1
Concentration Total Score (Digits + Months)	of 5

Figure 3. SCAT 5 Concentration Test

Table 1. Physiological Changes versus Memory Test Performance

		ΔPre Post RAVLT	ΔPre Post CONC	ΔPre Post IMMED	ΔPre Thirty RAVLT	ΔPre Thirty CONC	ΔPre Thirty IMMED	ΔPost Thirty RAVLT	ΔPost Thirty CONC	ΔPost Thirty IMMED
ΔPre Post HR	PC	-0.143	-0.059	-.570**						
	Sig	0.504	0.784	0.004						
ΔPre Thirty HR	PC				0.078	0.289	-.416*			
	Sig				0.715	0.170	0.043			
ΔPost Thirty HR	PC							-0.097	0.383	-.414*
	Sig							0.654	0.065	0.044
ΔPre Post SBP	PC	-0.083	0.215	0.253						
	Sig	0.700	0.314	0.233						
ΔPre Thirty SBP	PC				0.024	0.227	-0.158			
	Sig				0.911	0.286	0.460			
ΔPost Thirty SBP	PC							0.056	0.119	0.317
	Sig							0.796	0.581	0.131
ΔPre Post DBP	PC	0.011	0.320	-0.194						
	Sig	0.958	0.127	0.363						
ΔPre Thirty DBP	PC				-0.069	0.096	-0.263			
	Sig				0.747	0.654	0.214			
ΔPost Thirty DBP	PC							0.090	0.122	-0.178
	Sig							0.675	0.570	0.406
ΔPre Post O2	PC	0.176	-0.010	-0.078						
	Sig	0.409	0.963	0.718						
ΔPre Thirty O2	PC				0.162	-0.174	-0.096			
	Sig				0.450	0.416	0.657			
ΔPost Thirty O2	PC							0.102	0.379	-0.010
	Sig							0.635	0.068	0.964

PC = Pearson Correlation, Sig. = 2-tailed significance, n = 24
**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed)

4. Results

A bivariate correlation was run to analyze to relationship between the delta values of the physiological factors (ΔPrePostHR, ΔPreThirtyHR, ΔPostThirtyHR, ΔPrePostSBP, ΔPreThirtySBP, ΔPostThirtySBP, ΔPrePostDBP, ΔPreThirtyDBP, ΔPostThirtyDBP, ΔPrePostO2, ΔPreThirtyO2, ΔPostThirtyO2) and the delta values of the memory test scores. Changes in systolic blood pressure (SBP), diastolic blood pressure (DBP), and blood oxygen saturation (O2) did not significantly affect the results for any of the three memory tests, as all their p-values were greater than 0.05. Changes in HR did not significantly affect the results of the RAVLT or CONC assessments, but did significantly affect ΔPrePostIMMED, ΔPreThirtyIMMED, and ΔPostThirtyIMMED. In all three cases, HR values and IMMED scores showed significance with a negative Pearson coefficient, indicating an inverse relationship. This indicates that increasing a person's heart rate via exercise may initially lead to decreased immediate memory function, but later improve immediate memory function.

To further address the relationship seen with the bivariate correlation between changes in HR and changes in IMMED test scores, a dependent t-test was run. The dependent t-test showed whether the changes that occurred for HR and the changes that occurred for IMMED test scores were significant. The results of the dependent t-test for HR showed that ΔPrePostHR and ΔPostThirtyHR were both significant, but that ΔPreThirtyHR was not significant. This is as expected. When a person exercises, their heart rate will naturally increase. As the effects of exercise wear off, the person's heart rate will decrease back to resting values. Therefore, there is a significant difference between PreHR (resting) and PostHR (immediately following exercise) conditions. There is also a significant difference between PostHR and ThirtyHR (after thirty minutes of resting post-exercise). As expected, ΔPreThirtyHR was not significant because both PreHR and ThirtyHR conditions involved checking HR after resting. The results of the dependent t-test for IMMED test scores showed that ΔPrePostIMMED, ΔPreThirtyIMMED, and ΔPostThirtyIMMED were insignificant. Although the results of the dependent t-test show that the difference between IMMED test scores are insignificant, there could still be a general trend between changes in HR and changes in IMMED test scores, as indicated by the bivariate correlation.

Lastly, a repeated measures ANOVA was used to analyze the trend between changes in HR and changes in IMMED scores. The results of the repeated measures ANOVA showed that ThirtyHR < PreHR < PostHR and that ThirtyIMMED > PreIMMED > PostIMMED. This supports the inverse relationship between HR and IMMED scores that was found from the bivariate correlation. The repeated measures ANOVA revealed that IMMED scores tended to go down immediately following exercise, then increase to values above initial scores after resting for thirty minutes post-exercise.

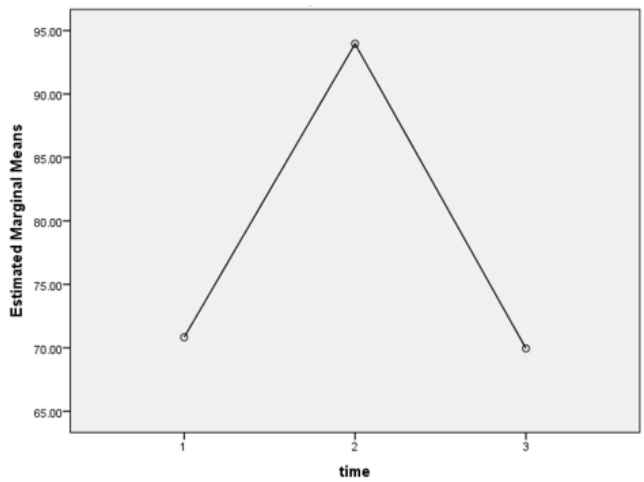

Figure 4. Repeated Measure ANOVA for HR

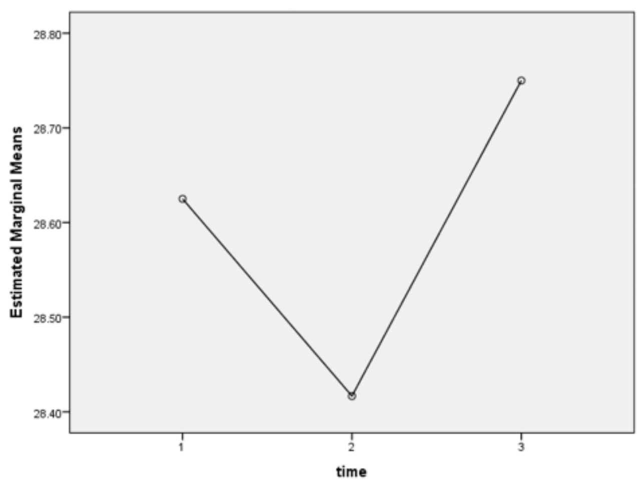

Figure 5. Repeated Measures ANOVA for IMMED

Table 2. Dependent T-Test

		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
Pair 1	PreHR - PostHR	-23.12500	17.72081	3.61725	-30.60784	-15.64216	-6.393	23	.000
Pair 2	PreHR - ThirtyHR	.87500	8.71936	1.77983	-2.80686	4.55686	.492	23	.628
Pair 3	PostHR - ThirtyHR	24.00000	18.10837	3.69636	16.35351	31.64649	6.493	23	.000
Pair 4	PreIMMED - PostIMMED	.20833	1.66757	.34039	-.49582	.91249	.612	23	.547
Pair 5	PreIMMED - ThirtyIMMED	-.12500	1.80127	.36768	-.88561	.63561	-.340	23	.737
Pair 6	PostIMMED - ThirtyIMMED	-.33333	1.90347	.38854	-1.13710	.47043	-.858	23	.400

5. Conclusions

This study analyzes the effects that a single bout of moderate intensity aerobic exercise has on short-term auditory-verbal memory, immediate memory, and concentration. The key findings of this study indicate a single bout of moderate intensity aerobic exercise does not significantly affect short-term auditory-verbal memory or concentration. This study also found that a single bout of aerobic exercise may have a positive delayed effect on immediate memory. Although immediate memory did not improve directly after the exercise protocol, there was a trend that was revealed that could be practically meaningful. Scores on the IMMED test tended to improve by 2.5% when comparing the results of the test taken thirty minutes post-exercise with the results of the test taken before exercise. Although these results were not conclusively significant, they may indicate a possible correlation with higher intensity or longer duration exercise and immediate memory function. Further testing may be needed to determine whether a single bout of aerobic exercise at a higher intensity or longer duration could have positive delayed effects on immediate memory at a significant level.

Research has been done analyzing the effects of maximal aerobic exercise on short-term auditory-verbal memory and concentration, and conclusions agree with the results of this study. A study conducted by Stroth, Hille, Spitzer, & Reinhardt, [20] had adults participate in 30-minute running sessions three days per week for six weeks. No difference was found in verbal memory or concentration performance between the exercised group and a control group, which indicates that exercise does not impact these aspects of cognition. Another study [22] used a free-recall memory test to assess short-term auditory verbal memory following treadmill exercise until voluntary exhaustion. Following the strenuous exercise protocol, participants were read a list of words to try to remember. When compared with a sedentary control group, exercised participants showed no difference in memory performance. The results of this study showed that high intensity aerobic exercise does not significantly affect short-term auditory verbal memory. Together, the results of these studies and the results of the present study indicate that short-term auditory verbal memory and concentration are not influenced by exercise of any intensity or duration.

Research also supports the conclusion that exercise benefits immediate memory. A study conducted by O'Brien, Ottoboni, Tessari, & Setti [14] divided 58 older adults into one of three groups. The first group participated in open skill exercise for 60-80 minutes, the second group participated in closed skill exercise for 60-80 minutes, and the third group served as a sedentary control group. The results showed improved immediate memory in both of the exercised groups. Another study [16] found that immediate word recall in children is improved by an acute, submaximal bout of group aerobic games. The results of this study suggest that cognitive function is enhanced exercise-induced physiological changes and by cognitive activation.

There are several proposed reasons behind the positive effect that regular exercise has on cognitive functions, including an increase in hippocampal neurogenesis [24] an increase in BDNF [7], an increase in cell density [23], the growth of various brain structures [4,5,25], a decrease in the prevalence of cardiovascular risk factors [6], and increased lactate [13,18]. Although these factors may contribute to enhanced cognitive function over time, many of them do not occur after a single exercise bout. Therefore, the trend toward enhanced immediate memory thirty minutes after a single exercise bout that this study concludes must be due to something else. Since HR appeared to have an inverse relationship with IMMED test scores in this study, it could indicate that the link between exercise and enhanced brain function as physiological in nature.

Some exercisers feel that physical exertion facilitates cognitive processing, while others report a debilitating effect [21]. The reported debilitating effect that exercise sometimes has on cognitive ability may be due to the fatigue factor. The fatigue factor would also account for the results of this study. Instead of cognitive performance increasing immediately following exercise, performance was not significantly changed. It could be that the fatigue factor associated with exercise counteracts the acute physiological benefits of exercise. However, once fatigue dissipates, the physiological benefits of exercise can be realized. One physiological phenomenon that could be linked to improvements in cognitive function that occur post-exercise is the "excess post-exercise consumption" (EPOC). EPOC refers to the increase in oxygen uptake that occurs during the recovery period following exercise. The magnitude of EPOC after aerobic exercise clearly depends on both the duration and intensity of exercise" [2]. EPOC could be the reason that ThirtyIMMED > PreIMMED > PostIMMED. More oxygen is available to be used by the brain thirty minutes post-exercise than pre- or immediately post-exercise. The greater amount of available oxygen allows for improved brain function thirty minutes post-exercise. Since the magnitude of EPOC depends on exercise intensity and duration, aerobic exercise at a higher intensity or longer duration could have more significant residual effects on immediate memory. It should also be noted that this relationship may only exist between immediate memory and aerobic exercise. Prior research indicates that potential cognitive benefits may be present following high intensity aerobic exercise, but not following high intensity resistance training [17].

In conclusion, moderate intensity aerobic exercise does not seem to have any positive or adverse effect on short-term auditory-verbal memory or concentration. However, it potentially has a positive effect on immediate memory. Although this study did not show the correlation to be statistically significant, it did show a trend that could be practically significant. The information gained from this study could assist researchers in determining what intensity and duration of exercise benefits specific aspects of cognitive function the most. Based on this study's results, further research should be done to determine whether aerobic exercise at a higher intensity or longer duration yields a statistically significant relationship with immediate memory performance.

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