Investigating the effect of moderate to intense aerobic and anaerobic exercise on oxygen saturation, visuospatial task performance, and short term working memory: implications for female student athletes ranging from sixteen to seventeen years old.

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Abstract

The study of the effect of moderate to intense anaerobic and aerobic exercise on cognitive function is important because studies have shown that different types of physical training directly impact cognition. However, little is known about the cardiovascular effects of different training intensities on short term working memory. The purpose of this study is to compare the effect of moderate to intense anaerobic and aerobic exercise on the short term working memory, specifically visuospatial, of 16-17 year old female student athletes.

Four female student athletes ranging from 16-17 years old were divided into two groups; one group performed anaerobic exercise and one group performed aerobic exercise. The participants' heart rates were recorded to validate and prove the different cardiovascular intensities. Oxygen saturation levels were measured with pulse oximeters. A visuospatial task exam that targets short-term working memory was taken before and after the exercise and exam performance was compared.

This study did not have a sufficient number of participants and will be further expanded upon with a larger sample size. Almost all the participants, regardless of which cardiovascular intensity they were assigned, experienced a decrease in oxygen saturation. Preliminary results indicate that participants performing the anaerobic exercise produced higher visuospatial exam scores after exercise completion, but results from the aerobic group are inconclusive. These limited results indicate that anaerobic exercise may enhance visuospatial memory skills. This study will allow athletes to make better decisions regarding how specific cardiovascular intensities affect their application of short-term working memory after a workout.

Background

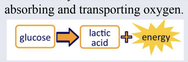
Working Memory

"Working memory refers to the ability to use, manipulate, and apply memory for a period of time" (Cherry). This study will be focusing on the lateral prefrontal cortex's ability to actively store visuospatial information (i.e. pattern development) for a short amount of time through its use of short term working memory.

- Short Term Memory: One's ability store a small amount of information and remember it for a short period of time. Short term memory cannot hold much information because of the short duration. Most people forget the information unless they use techniques to remember it. The information is easily replaced by more information in the specific time duration.

Anaerobic Exercise:

includes oxygen depletion and does not improve the efficiency of the cardiovascular system in absorbing and transporting oxygen.



Aerobic Exercise:

increases the body's demand for oxygen thereby resulting in marked temporary increase in respiration and heart rate.

Oxygen Saturation: the measure of the concentration of oxygen in the blood (%).

Review of Literature

Enhanced physical and cognitive performance in active duty Airmen: evidence from a randomized multimodal physical fitness and nutritional intervention. (Zwilling et al., 2020)

- The Air Force airmen were exposed to a strict exercise and nutrition regimen that was predicted to improve their physical and cognitive health.
- The participants were divided into two groups that were performing a unique mix of high intensity strength and cardiovascular exercises.
- One of the groups were given a nutritional drink that assists in increased performance and the other group was given a regular drink (placebo), but were unaware of the difference in substance, making this a double-blind control group/study.
- As the 12 weeks came to a close, the researchers noticed that the cardiovascular and endurance ability of each of the participants increased, as well as their cognitive functions.
- Both groups experienced increased strength and cognitive function, but the group who ingested the nutritional supplement produced more impressive results.
- Both these researches and my study of the effect of cardio and strength on cognitive ability focus on the growth or decline of cognitive functions in the brain.

Physical Exercise Increases Adult Hippocampal Neurogenesis in Male Rats Provided it is Aerobic and Sustained (Nokia et al., 2016)

- Suomen Akatemia's hypothesis regarding neurogenesis, the continued replenishing of neurons in the human brain's hippocampus, claims that aerobic exercise actually increases adult neurogenesis.
- The hippocampus and neurogenesis in general are both vital to for humans to continue learning and developing cognitively.
- Researchers from Department of Psychology and from the Department of Biology of Physical Activity at the University of Jyväskylä examined how running exercise, HIIT, and resistance training promotes neurogenesis in the hippocampus in adult male rats.
- The adult rats that "ran long distances and that also had a genetic predisposition to benefit from aerobic exercise" (Akatemia et al 2016) had increased neurogenesis in the hippocampus. Specifically, these adult male rats had two to three times more neurons in the hippocampus than the rats who did not perform any exercise. The HIT and resistance exercise did not result in a major increase of neurons.
- This study relates to my research because the researchers from Department of Psychology and from the Department of Biology of Physical Activity at the University of Jyväskylä examined the effect of aerobic exercise on neuron reproduction which relates to human cognition.

Purpose and Hypothesis

The purpose of this study is to assess the effect of moderate to intense anaerobic and aerobic exercise on the short term working memory of student athletes ranging from 16 - 17 years old.

It is hypothesized that the participants performing the moderate to intense anaerobic exercise will score lower on the visuospatial exam than the participants performing the moderate to intense aerobic exercise.

Alternative Approach

An alternate approach to this study would be to take a cognitive test after every period of moderate to intense exercise over the course of six months or a year. A more scholarly, advanced alternate approach could also include brain imaging after treatment to observe for any structural changes or differences within the lateral prefrontal cortex. An MRI Scan would examine the relationship between the designated neural circuits and inhibitory neuron activity.

Methods

1. Roughly 5 participants (female only) were recruited through convenience sampling. Each participant's age, athletic sport, gender, experimental group and cardiovascular medical history were recorded. Each participant sat down and took the visuo-spatial exam (corsi test) on their laptop; the scores were collected. Each participants' resting heart rate and maximum heart rate were calculated using Karvonen Theory.
2. A participant's target heart rate during physical exercise was based on their designated experimental group. Each participant had their oxygen saturation levels recorded before and after the experiment for comparison purposes. Three participants were observed engaging in testing and physical activity at a time.
3. Both the anaerobic and aerobic groups exercised for 15 minutes. The aerobic group ran non-stop at a designated heart rate (134 bpm - 152 bpm) while the anaerobic group completed a 2 minutes on - 1 minute off sequence at a designated heart rate (154 bpm -171 bpm).
4. In the last three minutes of the experiment, each participant had their heart rate and oxygen saturation levels recorded.
5. Immediately after the workout ended, every participant took the visuospatial exam (corsi test) again and the results were recorded; these results were used for comparison purposes. Oxygen saturation levels and heart rate were recorded roughly one minute after the exercise was completed.
6. The next participant began the preliminary visuospatial exam.

Dependent Variables:
- Participant Corsi Test Score After Experiment
- Participant Oxygen Saturation Levels During and After Experiment

Experimental groups:
- Anaerobic Exercise
- Aerobic Exercise

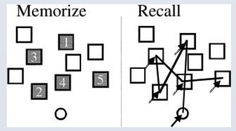
Control Variables:
- 10 Minute Warm Up Before Experiment
- Gender, Age
- Heart Rate Ranges: Anaerobic: 154 bpm -171 bpm; Aerobic: 134 bpm - 152 bpm

Karvonen Theory:

The Karvonen Theory contains is a set of equations created by a Scandinavian physiologist used to find maximum heart rate and heart rate reserve.
- The average resting heart rate for a 16-17 year old female is 79 bpm. The maximum heart rate is calculated by subtracting .88 of one's age from 206.
- Ex: 206 - .88(17) = 191 bpm

Figure 1: The Corsi Test: Philip Michael Corsi - 1972

The corsi test is an exam that consists of visuospatial (pattern-oriented) tasks that test short term working memory. Participants must recall the exact pattern of the specific blocks that flashed yellow during the exercise .The corsi test is measured in items.



Results

Both groups will be expected to attain a average corsi test score of 6 items before the experiment occurs. The anaerobic group is expected to score lower on the visuospatial exam than the aerobic group after the exercise is completed. It is hypothesized that this result is due to the major oxygen depletion during the actual anaerobic exercise and the recovery period.

The corsi test is measured in items or in other words, the number of blocks in a given sequence someone can remember. For example, a corsi test score of 2 means the participant was only able to memorize a sequence of two blocks.

Group: Anaerobic											
Participant	Age	Gender	Resting HR	Max HR	HR zone (bpm)	%O2 before	%O2 last 3 min	%O2 1 min after	Corsi Score befo	Corsi Score after	HR during
1AN	17	Female	77 bpm	191 bpm	154-171	99%	98%	97%	6 items	7 items	188 bpm
2AN	17	Female	72 bpm	191 bpm	154-171	92%	98%	97%	5 items	6 items	167 bpm
Group: Aerobic											
Participant	Age	Gender	Resting HR	Max HR	HR zone (bpm)	%O2 before	%O2 last 3 min	%O2 1 min after	Corsi Score befo	Corsi Score after	HR during
1A	17	Female	88 bpm	191 bpm	134-152	98%	96%	96%	3 items	5 items	189 bpm
2A	17	Female	54 bpm	191 bpm	134-152	93%	98%	97%	5 items	4 items	155 bpm

Figure 2: This data table show the variables that will be recorded throughout the experiment.

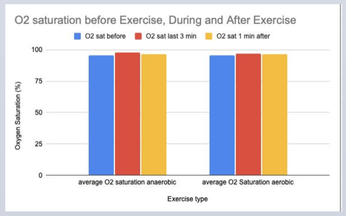


Figure 3: This graph shows the oxygen saturation levels of the participants before, during the last three minutes, and one minute after exercise completion.

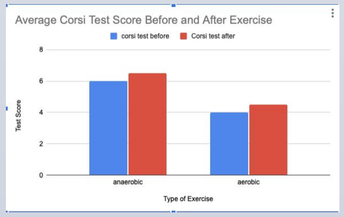


Figure 4: This graph shows a comparison of the anaerobic group's scores before and after the anaerobic exercise was completed; additionally, it shows a comparison between the aerobic group's visuospatial exam scores before and after the exercise.

Review of Literature (Continued)

Strong inhibitory signaling underlies stable temporal dynamics and working memory in spiking neural networks. (Kim et al., 2020)

- Short term memory normally is associated with excitatory neurons in the prefrontal cortex that extend and connect with one another all across the neural circuit, but through further investigation, scientists at the Salk Institute discovered that inhibitory neurons, which only have neural circuits in a designated area with more varieties of inhibitory neurons, actually contribute to the purpose of short term working memory.
- Sejnowski and Robert Kim created a model that was programmed to display information about the working memory of apes/monkeys. Both the model and real primates were introduced to a visuospatial sequence of "patterns of colored squares" (Salk Institute et al 2020).
- Both Kim's model and the brain activity of the primates operated on a slower timescale or took a second or two longer to recall the visuospatial task that they performed.
- This shows that long timescale neurons as well as neural circuit linkages between inhibitory neurons that regulate neurological activity are needed in order for successful short term memory function.

Effects of Physical Exercise on Working Memory and Attention-Related Neural Oscillations (Alondra et al., 2020)

- This study investigated whether four months of exercise impacted the theta and alpha power associated with working memory.
- The experiment required the participants to observe pattern sequences and specific objects in space.
- "Behavioral and electroencephalographic data" was collected from the researchers before and after the study for comparison.
- Out of the forty-three adolescent participants, the ones who performed the physical activity displayed enhanced frontal alpha power during the visuospatial tasks.
- This concludes that anaerobic exercise increases visual cognizance functions in sedentary adolescents.
- Both my study and Alondra's study discuss the effect of physical activity on working memory.

Neurocomputational Impact of Physical Training Overload on Economic Decision-making (Blain et al., 2019)

- Large amounts of mental focus and physical focus target the same part of the brain, the lateral prefrontal region. These tests show that "cognitive control" is not only essential for intelligence, but also for competitive sports and training.
- Here is a key question regarding a study performed on Olympic Athletes: Did this overtraining syndrome arise in part from neural fatigue in the brain -- the same kind of fatigue that also can be caused by excessive intellectual work?
- Researchers found that too much physical activity impacted the ability to make decisions and impulsivity "opting for immediate rewards instead of bigger ones that would take longer to achieve" (Pessiglione, Hôpital de la Pitié-Salpêtrière).
- This study showed that physical exertion can impact critical-thinking and decision making
- Pessiglione study directly relates to my study because both experiments focus on the function of the lateral prefrontal cortex after physical activity.

Discussion and Conclusion

It was hypothesized that the student athletes performing the anaerobic exercise would produce lower visuospatial exam scores because of the oxygen depletion present in the anaerobic respiratory processes to sustain the workout intensity. The results from this study indicate that almost all the participants, regardless of which cardiovascular intensity they were assigned, experienced a decrease in oxygen saturation. The heart rates of the anaerobic group were within the designated anaerobic parameters while the heart rates of some of the aerobic group were outside the designated aerobic parameters. The limited number of participants performing the anaerobic exercise produced higher visuospatial exam scores after exercise completion, but results from the aerobic group are inconclusive. The immediate goal of this experiment was to observe the negative effect of the major oxygen depletion during the actual anaerobic exercise and the potential oxygen distribution imbalance during the recovery period on the visuospatial exam results; therefore, my results do not support my hypothesis as the anaerobic participants experienced an increase in their visuospatial exam scores. This increase in visuospatial exam scores may indicate that exercise increases cognitive functions. A study focused on the effects of physical exercise on working memory and attention-related neural oscillations concluded that "the ones who performed the physical activity displayed enhanced frontal alpha power during the visuospatial tasks" (Alondra et al., 2020); this particular finding could act as vital reasoning for the increased visuospatial exam scores of my anaerobic participants. In terms of future studies, these results could indicate the potential ability of exercise to stimulate and increase the attention and visuospatial abilities of the prefrontal cortex. Complex brain imaging could identify the potential increased activity of the prefrontal cortex during exercise.

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