The Impact of Aerobic Exercise on Esport Performance – A novel and complex motor learning task

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Abstract:

Purpose/Hypothesis:
Esports, or competitive videogaming, is a growing sport. There are currently over 50 collegiate Esport teams across the US, and professional Esport viewing audiences already rival other professional sports. However, research on Esport performance is sparse. Acute bouts of aerobic exercise (AE) are known to improve acquisition and retention of novel motor tasks. Thus, the purpose of this study was to examine the effect of AE on Esport performance using a single-subject design. We hypothesized moderate aerobic exercise (M-AE) would improve immediate performance with minimal carry over, while intense aerobic exercise (I-AE) would result in long-lasting performance improvement.

Subject:
The subject was a 36-year-old male videogame player, who played an average of 20 hours per week. He had no prior exposure to the test game for this study.

Materials/Methods:
Esport performance was defined as the number of scored goals in 100 attempts on the popular Esport title Rocket League®. Performance was assessed twice weekly, with one session occurring immediately after either rest, 25 minutes of M-AE, or 15 minutes of I-AE at 65% or 80% of age predicted maximal heart rate respectively. The second assessment occurred 72 hours after the rest or exercise intervention. The subject was exposed to each condition twice. Physical performance measures of click speed, reaction time, grip strength, pinch grip strength, and hand-eye coordination were also measured at every session.

Results:
Large performance gains occurred over the first 3 sessions of baseline and rest conditions which were likely due to a learning effect. Mild gains were noted after the first round of M-AE, followed by a 26% performance increase after the first round of I-AE. The subsequent rest condition resulted in a 23% decrease in scoring. Reintroduction of M-AE resulted in another 22% increase, followed by a 4% increase after the final round of I-AE. Physical performance measures did not change between testing conditions.

Conclusions:
Improvements in scoring were consistently observed during each of the AE conditions. There was a large decrement in performance with the removal of AE for the second rest condition. Therefore, it is likely that AE enhanced performance gains. AE may enhance Esport performance via different processes such as cognitive priming and increased corticomotor excitability which implicate biological and psychological pathways as performance facilitators.

Clinical Relevance:
These findings suggest AE may be a beneficial tool for the Esport athlete to improve performance. The term “Esport performance” as described in this study is interchangeable with the phrase “novel and complex motor learning task.” As an adjunct to physical therapy interventions, it seems the application of AE has vast potential to create a facilitatory environment from which to engage in motor learning tasks with generalizability to numerous populations and settings of physical therapy practice.
Introduction:

Esports, or competitive videogaming, is a growingly recognized sport. There are currently over 50 collegiate varsity esports teams across the United States, with some offering scholarships to student athletes. As a whole, esports is expected to become a $1.5 billion-dollar industry by the year 2020 and already boasts viewing audiences which rival the other 4 major professional American sports. The International Olympic Committee has even discussed the potential of making esports a sanctioned Olympic event for the Summer 2024 games in Paris. The legitimacy of esports as a professional and competitive entity is no longer in question, though little to no evidence exists in the literature regarding performance enhancement for the esport athlete. Some of this may be contributed to the inherent difficulties in breaking down videogame performance to component parts required for objective measurement. Perhaps another reason for the lack of evidence involves reluctance to recognize esports as an actual “sport” or recognize its competitors as “athletes”.

Aerobic exercise is known to promote positive health benefits such as reducing risk of cardiovascular disease, reducing risk of age-related cognitive decline, accelerating recovery after neurological insult, improving attention and executive function, increasing brain activation and blood flow, and increasing brain volume in key areas for memory including the hippocampus. The ACSM defines cardiovascular exercise as a “type of physical activity that uses large muscle groups, can be maintained continuously and is rhythmic in nature”. More recently, the effects of acute bouts of aerobic exercise have been studied as a facilitator to the encoding and consolidation phases of motor memory.

Acute bouts of aerobic exercise have been shown to improve acquisition and retention of novel motor tasks through numerous pathways. Aerobic exercise and variables such as timing/intensity exert influence on motor memory via psychological, neuroendocrinological, and biological pathways.

Moderate intensity aerobic exercise (defined as 55-70% of age-predicted maximal heart rate) has been shown to facilitate acquisition of novel motor tasks via both psychological and biological pathways. Cognitive priming and improved awareness are the proposed psychological mechanisms and increased corticomotor excitability is the proposed biological mechanism. Exercise increases sympathetic tone, blood flow, and neuronal activity which facilitates activation and processing efficiency of the primary motor cortex (M1 area) of the brain. Singh et al. (2014) utilized Transcranial Magnetic Stimulation to probe the excitability of descending motor tracts of a non-exercised upper extremity muscle (Extensor Carpi Radialis) after lower extremity exercise. Their results suggested exercise does not modulate the firing threshold of motor neurons, but does prime/facilitate neuromuscular processes via decreased intra-cortical inhibition and facilitation of intra-cortical processing.

Intense aerobic exercise (defined as 75-85% of age-predicted maximal heart rate) has been shown to facilitate retention of novel motor tasks. This theory proposes transient improvements in motor memory are likely attributed to factors which are also transiently increased after bouts of intense exercise. The exercise-induced proliferation of catecholamines, hormones, and
proteins stimulate the induction, up-regulation, or down-regulation of various cascades which lead to angiogenic or neurogenic response in the brain\textsuperscript{10,11,12}. Increased circulating levels of these neuroendocrinological factors are directly predicted by increasing the intensity of aerobic exercise. Circulating blood lactate is an objective biomarker which is also indicative of increased circulating Brain-Derived Neurotrophic Factor (BDNF). BDNF is a protein responsible for inducing a signaling cascade which improves use-dependent behavioral aspects of learning (ie. acquisition and retention) within the hippocampus. The interplay of blood lactate, BDNF, Insulin-like Growth Factor 1 (IGF-1), Vascular Endothelial Growth Factor (VEGF), Catecholamines, and Cortisol are responsible for the various neuroplastic processes theorized to improve the consolidation of novel motor memories\textsuperscript{13,14,15}.

To summarize, it seems moderate intensity aerobic exercise improves the immediate and subsequent acquisition of novel motor tasks via mechanisms which implicate cognitive priming and corticmotor excitability. Intense aerobic exercise seems to benefit the retention of novel motor tasks by inducing biological changes in the brain which are stimulated by increased circulating levels of neuroendocrinological factors. The above findings are summarized in \textit{Figure 1}.

\textbf{Figure 1}
Purpose:

The purpose of this study was to assess the influence of acute bouts of varying intensity aerobic exercise on the performance of a novel and complex motor learning task, namely esport performance. Performance on the popular esports title Rocket League® was utilized as the dependent variable for this study. We hypothesized moderate aerobic exercise would improve immediate performance with minimal carry over, while intense aerobic exercise would result in long-lasting performance improvement.

Methods:

Participant

A single subject was recruited via convenience sampling for the current study. The male subject was 36 years old, measured 5’7” (67 inches) and weighed 196 lbs. (89 kg). Care was taken to recruit a subject for whom videogaming in itself would not be a novel task, but whose exposure to the test game within the study (Rocket League®) was limited. The subject reported via a self-completed subjective questionnaire an average of 20 weekly hours appropriated to playing videogames over the past 2 months in comparison to 0 career hours appropriated to Rocket League®. Cardiovascular risk was screened in accordance with the Par-Q and You as well as the AHA/ACSM Health and Fitness Pre-participation Screening Questionnaire.

Experimental Design

A repeated and sequential single-subject experimental design was utilized to expose the subject to all testing conditions over the course of 6 weeks. Prior to initiation of the study, a control session was completed to establish baseline scoring. Esport performance was operationally defined as the number of goals out of 100 attempts within a custom designed training module in Rocket League®. Physical performance measures deemed relevant to esport performance were also assessed to determine baseline values.

The subject completed the Rocket League® training module immediately after either a period of rest (no exercise), moderate intensity aerobic exercise (65% APMHR for 25 minutes), or intense aerobic exercise (80% APMHR for 15 minutes). A retention test identical to the training module was administered within a period of 48-72 hours after each testing conditions. A sequenced outline of the study has been provided in Figure 2.
Exercise Procedures

Repeated testing conditions were employed to expose the subject to both exercise interventions twice. A repeated and sequential design was imperative to mitigate any potential learning effects as the testing scenario was identical at every session. Cycle ergometry was the mode of aerobic exercise chosen for the study and performed on the Monark Ergomedic 828E bicycle in an outpatient physical therapy clinic based in Miami, FL.

For the purposes of the present study, moderate intensity aerobic exercise was defined as 65% of the subject’s APMHR (119 bpm +/- 8 bpm) for a period of 25 minutes at a workload of 0.5 Kp. The subject’s heart rate was manually recorded every 5 minutes at his right radial pulse. Pedaling cadence was accordingly increased or decreased in order to ensure the correct APMHR range was achieved throughout the session of aerobic exercise.

Intense aerobic exercise was defined as 80% of the subject’s APMHR (147 bpm +/- 8 bpm) for a period of 15 minutes at a workload of 0.5 Kp. As in the case of moderate aerobic exercise, pedaling cadence was continuously adjusted accordingly to ensure the correct APMHR was maintained throughout the exercise session.

The subject was given a brief warmup on the Monark ergometer set at the Kp required for the respective exercise condition. The subject was asked to begin pedalling at a cadence of 50 revolutions per minute. Heart rate was assessed every 45 seconds with the subject being asked to increase their cadence by 10 rpm until the target HR for the respective condition was achieved. Once target heart range was attained the exercise session began.

At every 5 minute interval during exercise HR, Borg RPE, and RPM were recorded.
Performance Measures

Performance measures were recorded at baseline and prior to completion of the Rocket League® training module at every exercise session. Hand-eye Coordination, Click Speed, Reaction Time, Grip Strength, and Pinch-grip strength were objective measures deemed relevant to predicting videogame skill. None of the above measures have been validated for use within the videogaming population, though their selection was assumed to translate to the requisite skills required at the professional esports levels.

In the context of the current study, these performance measures were used to determine if improved performance as measured on the Rocket League® module are attributable to motor learning or to increased awareness, neuromuscular priming, and intracortical facilitation resulting from having completed an acute bout of aerobic exercise. The performance measures were operationally defined as:

- **Hand-eye coordination** – The ability to process visual input and provide an accurate motor response with respect to speed and proprioceptive awareness. Measured as successful catches on an alternating ball wall toss test in 30 seconds.

- **Click Speed** – The rapidity of an isolated motor response from a starting position to a static target as measured by clicks per second.

- **Reaction Time** – The rapidity of an isolated motor response to the appearance of a visual stimulus with a variable and unpredictable time between appearances as measured in milliseconds.

- **Grip Strength** – Pounds of force generated in either the dominant or non-dominant hand with a normal grip.

- **Pinch Grip Strength** – Pounds of force generated in either the dominant or non-dominant hand in a key-pinchoff position, which replicates the standard functional grip required when playing a console-based videogame.

Esport Performance

As stated previously, esport performance was defined as the percentage of scored goals out of 100 shot attempts on a custom training scenario designed within Rocket League® by the lead investigator. The videogame was played on the Playstation 4® console with a dualshock 4 controller®. In Rocket League®, teams composed of usually 3 players drive different cars in an open arena while trying to score a ball into the opposing team’s goal. In layman’s terms it is essentially soccer played with cars. The training scenario was kept identical throughout each test condition with the same in-game arena, in-game time of day, in-game vehicle, and shots being employed.

Because of repeated exposure to identical testing conditions it was determined that the score achieved after each training session would serve as the baseline for the subsequent testing.
condition. In other words, a subject would have to continually improve their score after each testing module to justifiably assert performance improvement had occurred.

The subject’s heart rate was also recorded at 2 random points during each testing condition in order to assess the cardiovascular and stress response associated with playing a videogame with greater than recreational investment.

![Image](image.jpg)

**Results:**

As demonstrated in Figure 3, and consistent with our hypothesis, performance steadily increased throughout the study. This was expected as the subject was repeatedly exposed to the same testing condition throughout the study (a total of 13 times). Over the course of the study, esport performance more than doubled from baseline scoring. Recalling our initial hypothesis, it seems our claims were at least partially supported. The completion of either moderate or intense aerobic exercise resulted in spikes during subsequent esport performance.
The greatest single session in which improved performance occurred was after the 1st round of intense aerobic exercise. This condition resulted in a 26% scoring increase from the previous session. Our hypothesis asserted that the biological, psychological, and neuroendocrinological benefits of aerobic exercise would result in immediate, and potential long-lasting, changes in esport performance. We found that introducing a week of rest in the middle of our study resulted in a net 23% decrease in performance, almost back to initial baseline rest-condition values. The elimination of aerobic exercise, therefore, seemed detrimental to the observed gradual and continuous improvement in scoring between sessions. Figure 4 highlights the percent change noted at each testing session. Percent change was calculated on a session-to-session basis with scoring during the previous session serving as the new baseline for measurement.
Heart rate was an important objective measurement frequently recorded during our study as a means of ensuring proper dosage of aerobic exercise and to assess the “stress” induced on our subject during videogame play. Like any other athlete experiences increased sympathetic arousal during competition, it is assumed an esport athlete would similarly demonstrate such a disposition. While our study did not simulate an environment of competition, it did create a scenario of videogame play with at least greater than recreational investment. Interestingly, in the absence of exercise it seems testing conditions did not provide enough of a sympathetic stimulus to reflect significant changes in resting heart rate. The performance of both moderate and intense aerobic exercise resulted in predictable increases in heart rate consistent with the intensity of exercise. An unexpected finding during data collection was that the playing through the Rocket League® module after the performance of either moderate or intense aerobic exercise blunted heart rate recovery. During initial baseline data collection, a graded exercise test was completed with our subject demonstrating a heart rate recovery of 35 beats per minute. During the first round of intense aerobic exercise heart rate was recorded at 120 beats per minute just prior to initiating gameplay (approximately 5 minutes after the completion of exercise). At the conclusion of the Rocket League® module (approximately 20 minutes after the completion of exercise) the subject’s heart rate was recorded at 106 beats per minute. The subjects heart rate had only decreased by 14 beats per minute over a period of 15 minutes, when it was previously established that their cardiovascular system was robust enough to produce a heart rate recovery of 35 beats per minute. The difference between both conditions being whether rest or videogaming followed an exercise session. Figures 5 and 6 detail the described variability in heart rate.
Resting Heart Rate Before Gaming
(5 mins after exercise)

Figure 5

Heart Rate during Attempts 51-100
(20 mins after exercise)

Figure 6
**Discussion:**

The results of the current case study suggest two distinct ideas which warrant more rigorous and controlled investigation. These ideas being:

1. The performance of aerobic exercise prior to engaging in videogaming may facilitate esport performance.
2. Performing a stimulating cognitive-motor task, such as videogaming, after exercise may blunt heart rate recovery and parasympathetic tone.

The assertion that aerobic exercise may facilitate esport performance is both novel and beneficial to a population for whom the performance enhancement realm has yet to be explored. As discussed in the introduction of this paper, research over the last 10-15 years has revealed moderate intensity aerobic exercise benefits motor acquisition via biological and psychological pathways. Intense aerobic exercise benefits retention of novel motor tasks via largely neuroendocrinological mechanisms and the predictable relationship between increased exercise intensity with increased circulating levels of blood lactate, BDNF, catecholamines, and cortisol. Consistent with prior research, we hypothesized our subject would demonstrate a greater percentage improvement after bouts of moderate aerobic exercise with minimal carry-over, and demonstrate a more limited percentage improvement after bouts of intense aerobic exercise but show much higher carry-over. Our results did not directly correlate with findings from previous literature, though we believe greater consistency and correlation would have been achieved with a greater number of test subjects. Our subject also exhibited a higher resting heart rate (~80 bpm) than we expected for a person of his age and physical activity level. This finding could have skewed our data and impacted the proper dosage of moderate and intense aerobic exercise. The performance of a VO2Max test to determine baseline values such as a respiratory exchange ratio would have mitigated any errors presented by the subject’s resting heart rate.

Despite our results not directly correlating with previous research regarding motor acquisition and retention, we did find that aerobic exercise positively impacted esport performance as defined in this study (see figures 3 and 4). The two greatest percentage improvements observed occurred after bouts of aerobic exercise (the first session of intense and the second session of moderate- to be specific). Perhaps the most important finding, however, was the decrement in performance noted in the middle of the study when esport performance was assessed in the absence of aerobic exercise. Using a repeated and sequential design allowed us to differentiate whether observed effects were in fact due to aerobic exercise or associated with repeated exposure to the same stimulus.

Regarding the physical performance measures recorded at every session (hand-eye coordination, click speed, reaction time, grip strength, and pinch-grip strength), we found no significant changes between any condition. This indicates aerobic exercise did not lead to any directly physically observable changes in motor recruitment, motor strength, or visuomotor response time/coordination within a session. Improved performance must therefore be attributed to learning effects occurring between sessions, increased executive function, and improved decision making during gameplay facilitated by aerobic exercise.
The second major discovery of our study was unanticipated though equally important. With a recorded heart rate recovery of 35 beats per minute and the finding that videogame play under resting conditions did not alter heart rate, we would have expected our subject’s heart rate to decrease to baseline values during videogame play after exercise rather quickly. This was not the case. The finding that videogame play blunted heart rate recovery in this case study, and consequently parasympathetic tone, provides relevant information regarding esport performance enhancement and recovery. The development of a tailored performance program for professional esport athletes may have to contend with the possibility that practicing after performing exercise may hinder the rest-recovery cycles beneficial for cognitive and motor memory encoding as well as muscular adaptation.

**Limitations**

Our case study did have to contend with several limitations, despite effort to control as many extraneous variables as possible. The first, inherent with many case studies, regards the potential to generalize results due to having only one subject. Our findings would yield more power had they been confirmed over multiple subjects randomized into different conditions. Having multiple subjects may also have allowed us to observe the results we expected in our hypothesis, with moderate aerobic exercise improving immediate esport performance, and intense aerobic exercise facilitating improved retention. As stated previously, our test subject exhibited a resting heart rate higher than what would be expected for a person of his age and physical activity level. This consequently affected his response to aerobic exercise and the subsequent dosage of exercise intensity for the testing conditions. With multiple test subjects we would have been able to capture a wider proportion of resting heart rates and thus assess more specifically the response to moderate and intense exercise. Participant blinding was also not possible as our subject was fully aware to a general sense of the purpose of the study.

Another limitation involved our testing environment. Every session involving exercise and Rocket League® performance was conducted in an outpatient physical therapy facility in Miami, FL. All other sessions were conducted in the subject’s home. Not only was the environment different, but the testing monitor for both scenarios was also different. While the extent of the differing environments is unknown and therefore introduce bias, their effects should not be viewed with extreme weight as our subject’s scoring was rather consistent in both environments.

**Conclusions:**

This case study is among the first investigative efforts in the realm of esport performance enhancement. A growing professional sport and community requires an equally budding effort on behalf of the scientific community regarding performance cultivation, injury prevention, and wellness promotion. Recent evidence has demonstrated the benefits of moderate intensity aerobic exercise on motor acquisition and the benefits of intense aerobic exercise on motor retention of novel tasks. Our study attempted to extrapolate these findings to the realm of esports.

According to our results, we determined aerobic exercise seems to facilitate both immediate and delayed esport performance. We believe aerobic exercise facilitates cognitive priming,
corticomotor excitability, and intracortical facilitation which leads to improved executive function and decision making during game play as the rationale for the immediate improvements seen after aerobic exercise. Delayed improvements in esport performance are likely due to the creation of motor planning strategies and neuronal schema’s induced by increased circulating neuroendocrinological factors like blood lactate, BDNF, and VEGF. We also discovered immediate videogame play after completing aerobic exercise blunted heart rate recovery which is mediated by the parasympathetic system. This finding poses potential implications in the development of esport enhancement programs.

Future research is legitimately warranted in this area in order to generalize findings to the esport community at large. The most logical place to begin would involve operationally defining relevant aspects of esport performance as a means of creating objective measures from which to define performance, predict gamer skill, and establish a common language for researchers to communicate. From there, an array of potential avenues may be explored to ultimately provide esport athletes with the tools needed to hone their craft.
References:


