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Blood glucose levels in response to 1 hour of esports training: A pilot study

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Abstract

Aims**:** The purpose of this study was to determine the relationship between blood glucose levels and performance in esports.

Methods and Results**:** Ten college-aged participants (9 male, 1 female; age = 20.3 ± 1.2 years; BMI = 28.8 ± 7.6; esports mean hours per week = 18.9 ± 14.3) were recruited. In a cross-over counterbalanced design, participants completed two esports sessions (fed & fasted) following an 8 hour fast. An initial baseline blood glucose measurement was recorded (Baseline) after which, participants received either a nutrition bar or remained fasted. There was a one-hour rest period before blood glucose and mental fatigue were recorded (Pre). Each experimental visit included two 60-minute esports sessions while gaming performance were recorded. Blood glucose was measured at baseline, pre, 30 minute, and post (2-hours post-bar). Mental fatigue and enjoyment levels were recorded at the end of the session (Post). Mean blood glucose was significantly higher at the Pre (110.8 ± 25.3mg/dL vs 90.9 ± 9.4mg/dL, p = 0.045), 30 Min (96.3 ± 10.3mg/dL vs 84.9 ± 89mg/dL, p

= 0.002), and Post (91.9 ± 5.7mg/dL vs 83.7 ± 7.0mg/dL, $p = 0.011$) recordings during the fed session in comparison to fasted. Mental fatigue was not significantly affected by session and/or time.

Conclusion: There was no increase in esports performance ($p > 0.05$). Further research should be conducted to continue to explore the relationship between blood glucose levels and esports performance.

Highlights

- Mean blood glucose was statistically significantly higher at Pre (110.8 ± 25.3mg/dL vs 90.9 ± 9.4mg/dL, p = 0.045), 30 Min (96.3 ± 10.3mg/dL vs 84.9 ± 89mg/dL, p = 0.002), and Post (91.9 ± 5.7mg/dL vs 83.7 ± 7.0mg/dL, p = 0.011) in the fed trial in comparison to fasted.
- No statistically significant differences in esports performance were observed (p > 0.05) when comparing fed to fasted sessions.
- No statistically significant differences in mental fatigue and enjoyment levels were observed (p > 0.05) when comparing fed to fasted sessions.

***Keywords*:** fasted, video games, aim trainer, osu, performance, mental fatigue

Introduction

Esports (Electronic Sports) is a rapidly growing field of competitive video gaming that has become a dominant figure in the entertainment industry in recent years (1). It is a blanket term that includes many different video games that are played competitively, where either solo individuals or coordinated teams are pitted against one another. In 2019, esports surpassed 1.7 billion viewers with a total revenue of 1.096 billion dollars (2). Both the International Olympic Games Committee and the Asian Games have recognized esports as an official sport, and it has also solidified a place in collegiate sports with multiple schools adding esports to their athletic programs (2–4). In these competitions, quick response time, team coordination, and mechanical prowess are all key requirements for victory.

There have been a significant number of studies conducted on the effects of varying blood glucose levels on cognitive function (5–9). The brain has greater metabolic activity than any other organ within the human body. By mass, it makes up only 2% of the body, but it has an energy requirement of nearly 20% of total energy expenditure at rest (7,10). Although it requires a constant supply of fuel, it does not contain substantial stores of glycogen for energy production. This means that the brain relies on blood glucose to meet its energy needs. This circulating glucose is transported through the blood-brain barrier into the extracellular fluid at a rate directly proportional to the local capillary surface area (7). Previous reports have suggested that specific compartments of the brain contain varying levels of glucose in their extracellular fluid in a ratio directly linked to neural activity in those areas. This increased use of glucose within the brain for cognitively demanding tasks is correlated to a measurable decrease in circulating blood glucose, which suggests that blood glucose measurements could be used as a marker for increased glucose uptake and usage in the brain (11). Researchers typically observe elevated blood glucose concentrations following subsequent consumption of glucose-rich substance with an associated increase in performance in cognitively demanding tests (6–8,10). However, less demanding cognitive tests observe smaller improvements or no significant increase at all (7,10). Previous research conducted on this topic has utilized a wide range of tests to determine the effect of glucose on cognitive function including serial subtraction, the Stroop paradigm, rapid information processing, driver simulations, word retrieval, and the Porteus maze test (6,7,10). An increase in performance was observed across all modalities post consumption of a glucose-rich beverage (25-50g at 20-45 minutes prior), with the most pronounced increases occurring on tasks considered most cognitively demanding (6,7,10). Further, connections between fluctuations in glucose levels with increased performance have been noted, with greater decreases in blood glucose corresponding to increased utilization of glucose within the body during particularly taxing tests (10). Interestingly, this paradigm has yet to be examined within esports, even though several studies have previously demonstrated this field's high cognitive demands (12–14).

Despite the success of esports and its acceptance as a variant of sports, there has been very little research conducted on esports athletes. Due to the absence of published literature, the physiological responses, nutritional requirements, and cognitive demands associated with engaging in esports remain unclear. Given the potential increased cognitive demands elicited by esports, the nutritional status (fed vs. fasted) could impact an individual's blood glucose levels and subsequently their esports performance. Therefore, the purpose of this study was to determine the impact of blood glucose levels on esports performance.

Methods

Participants

After obtaining approval from the University of Mississippi's Institutional Review Board, ten undergraduate students (9 male, 1 female; age = 20.3 ± 1.2 years) were recruited from the esports club at the University of Mississippi. Eligibility was limited to individuals who played at least 6 hours of esports per week and were not diagnosed with type I or II diabetes mellitus or a peanut allergy. All procedures conformed to the ethical considerations of the Declaration of Helsinki. After an initial review of eligibility criteria, participants signed informed consent forms prior to participating in the study. Participants completed the informed consent and a medical history inventory prior to being admitted to the study.

Procedures

Three study visits were required to complete the study. During the initial visit, the participants completed the health, exercise, and esports training history forms. These questionnaires required the participants to report the number of hours they engage in esports per week, average daily caffeine consumption, age, and questions that were used to determine if the participants met the eligibility criteria. Following, height and weight were recorded using a Detecto scale (Webb City, MO). The initial visit included a one-hour familiarization session to the training programs Aim Hero and *osu!*. During the familiarization, mouse/game sensitivities were calibrated to each player. At the conclusion of the initial session, participants were scheduled for the first experimental visit and were instructed to fast for at least 8 hours prior to the session. They were also instructed to avoid deviating greatly from their normal sleeping habits and were informed to duplicate the same sleeping schedule for the third visit. In this randomized controlled trial, participants were randomly assigned to complete the fasted gaming visit or fed gaming visit first in a counterbalanced cross-over order. Subsequent visits occurred after a minimum of 24-hours and all visits were completed within 2 weeks of the initial baseline session.

Esports Training Sessions

For both the fed and fasted visits, participants arrived at the lab during the morning at a fasted state. Upon arrival, blood glucose levels were measured (Baseline) to confirm the fasted status (> 8 hours). During the fed trial, participants ingested a Cliff bar (Emeryville, CA; 21 g of sugar, 250 kcals) and then rested in a seated position for one hour. At the end of the rest period, a second blood glucose measurement (Pre) was assessed and participants were asked to rate their mental fatigue level. Participants then completed a total of 60-minutes of gaming using two esports training platforms in a counterbalanced design, Aim Hero and *osu!*, for 30-minutes each. Blood glucose concentration was measured at the conclusion of the first 30-minute esports training session (Aim Hero or *osu!)*. Participants would then complete the final 30-minute esports training session on whichever was not utilized in the first 30-minute session. Following the end of the second esports training session, blood glucose, mental fatigue, and enjoyment levels were measured (Post). All procedures performed during the fed visit were identical to the fasted visit, except the consumption of the Cliff bar.

osu!

osu! is a rhythm-based computer game in which circular targets and "sliders" appear around the computer screen for the player to click and/or drag using the mouse cursor. While this game has its own active esports community, it is also used by professional athletes of other games to practice or warm-up (15,16). The targets appear on the screen following the rhythm of a song which it refers to as a "beatmap." The beatmaps are rated based on difficulty (i.e. the number of targets and speed in which they appear), and each map has many different difficulty options. Three beatmaps were selected from a database based on both song length and number of separate difficulties. Player performance is based on both accuracy and precision with regards to clicking the targets/sliders on the screen. The number of misses and largest combo (the greatest number of consecutive targets hit without missing) also play a role in the player's performance. Participants were familiarized with *osu!* during the first visit, during which, beatmap difficulties were calibrated to each participant to ensure a challenging experience.

Aim Hero

Aim Hero (ProGames Studio 2016) is an aim-training program for the computer which offers multiple game variants targeted at improving specific aspects of aiming that are necessary in other first-person shooter games. The game variants utilized in this study included: classic, reflex, simple, and time trial. In classic, targets continually appear around the screen at a speed that increases with time, and the player is required to shoot each target to destroy it. The targets disappear after approximately six seconds, and if the player allows five targets to disappear during a level, then the round ends. In the reflex game variant, a single target briefly appears in a random location on a two-dimensional surface in front of the player. This happens once approximately every second for three minutes. In simple, a single, moving target appears somewhere in a three-dimensional firing range and remains until the player has destroyed it. Once it has been destroyed another target appears at a random location, and this sequence continues for three minutes. In time trial, the participant is positioned within a large three-dimensional arena with targets surrounding (360°) them at varying distances. The player's goal is to shoot fifty targets as fast as possible.

Blood Glucose Testing

Blood glucose levels were measured using a HemoCue Glucose 201 Analyzer (Angelhome, Sweden) a total of 8 times (4 per visit). Blood samples were obtained using standard procedures and sterile techniques. Participants were seated in the lab and had their finger cleaned using sterile alcohol pads. Light pressure was applied to the participant's fingertip on their left hand (non-computer mouse hand) which was then punctured using a lancet (drawn samples of less than ½ mL). Blood was then collected in a capillary cuvette and analyzed. Glucose measurements occurred at Baseline, Pre, 30 Minutes, and immediately Post.

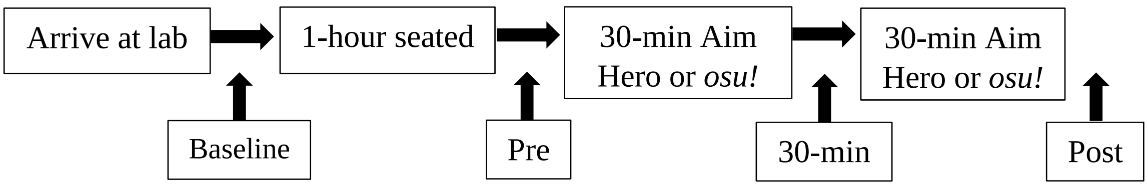

Figure 1 - Blood Glucose Measurements for Fed vs. Fasted 2-hour visits. Blood glucose was measured at Pre, 30 min, and Post time points. The order in which *osu!* or Aim Hero were performed was counterbalanced across the participants.

Enjoyment Level

Participants rated their enjoyment level using a 10cm visual analog scale upon completion of the one-hour gaming session. They did this by creating a mark on a 10cm line which ranged from not enjoyable (leftmost point) to highly enjoyable (rightmost point). A ruler was then used to measure the distance of the mark from the left side of the line with this distance in cm corresponding to the enjoyment level on a 1-10 scale.

Mental Fatigue Scale

Participants self-reported their mental fatigue level directly prior to and following the one-hour gaming portion of each session. Their response was based on a scale ranging from 1 (fully alert) to 7 (completely exhausted).

Data Analysis

Statistical analyses were performed by utilizing a 2 x 4 [Visit (fed, fasted) x Time (Baseline, Pre, 30 Min, Post)] factorial ANOVA with repeated measures for blood glucose levels. A 2 x 2 [Visit (fed, fasted) x Time (Pre, Post)] repeated measures ANOVA was utilized to examine perceived mental fatigue. Paired samples t-tests were utilized to compare mean game variant performance and enjoyment scale ratings. Significant within-visits and within-time differences were determined using Fisher's Least Significant Difference posthoc test. If the within-group assumption of sphericity was violated using Mauchly's Test of Sphericity, the Greenhouse-Geisser correction factor was used to evaluate observed within-group F-ratios to protect against Type I error. Main effects were investigated using separate one-way repeated-measures ANOVA. Statistical procedures were performed using SPSS 26.0 software (Chicago, IL) and an alpha of 0.05 was adopted throughout.

Results

Table 1 - Participant Demographics (n=10)

Variables	Mean ± SDan ± *SD*
Age (years)	20.3 ± 1.2
Height (cm)	179.3 ± 4.5
Bodyweight (kg)	92.5 ± 23.7
BMI	28.8 ± 7.6
Avg. Daily Caffeine (mg)	103.0 ± 102.7
Esports Hours Per Week	18.9 ± 14.3

Blood Glucose Levels

There was not a statistically significant visit x time interaction for blood glucose levels [$F_{(3,77)} = 2.162$, $p = 0.1$]. The main effect of visit (fed/fasted) revealed significant differences for glucose levels between visits [$F_{(1,79)} = 11.396$, $p = 0.001$]. The main effect of time (Baseline, Pre, 30 Min, Post) demonstrated significant differences for participant blood glucose levels among timepoints [$F_{(3,77)} = 3.792$, $p = 0.014$]. Post-hoc analysis revealed that mean blood glucose was significantly higher at the Pre (110.8 ± 25.3mg/dL vs 90.9 ± 9.4mg/dL, $p = 0.045$), 30 Min (96.3 ± 10.3mg/dL vs 84.9 ± 89mg/dL, $p = 0.002$), and Post (91.9 ± 5.7mg/dL vs 83.7 ± 7.0mg/dL, $p = 0.011$) recordings during the fed session in comparison to fasted. No statistically significant differences were observed between baseline values ($p = 0.424$). Blood glucose levels statistically significantly decreased between the pre and post measurements for both the fed ($p = 0.030$) and fasted ($p = 0.045$) visits.

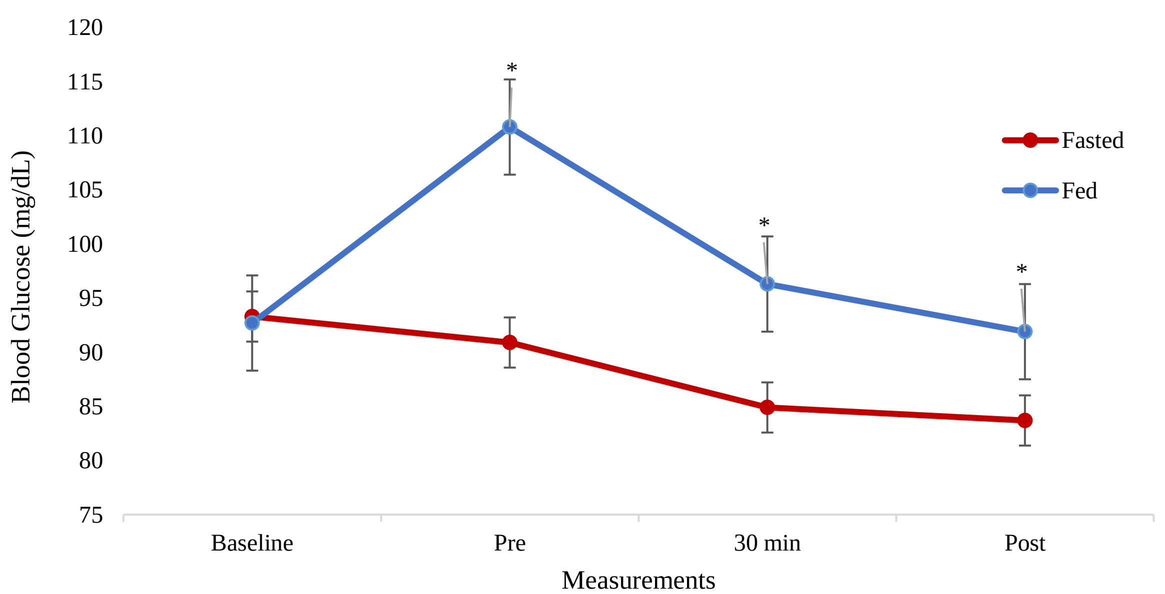

Figure 2 - Fed vs. Fasted Blood Glucose Measurements. Timepoints represent the mean ± standard error. * denotes statistical significance (p < 0.05) for the Pre, 30 min, and Post time points when comparing fed versus fasted levels. The order in which *osu!* or Aim Hero were performed was counterbalanced across the participants.

Mental Fatigue

The main effects of the 2 x 2 factorial ANOVA showed no significant relationship between mental fatigue and session type (fed/fasted) [$F_{(1,39)} = 1.791$, $p = 0.189$] or between mental fatigue and time (pre/post) [$F_{(1,39)} = 2.676$, $p = 0.111$]. There was also no statistically significant visit x time interaction [$F_{(1,39)} = .199$, $p = 0.658$].

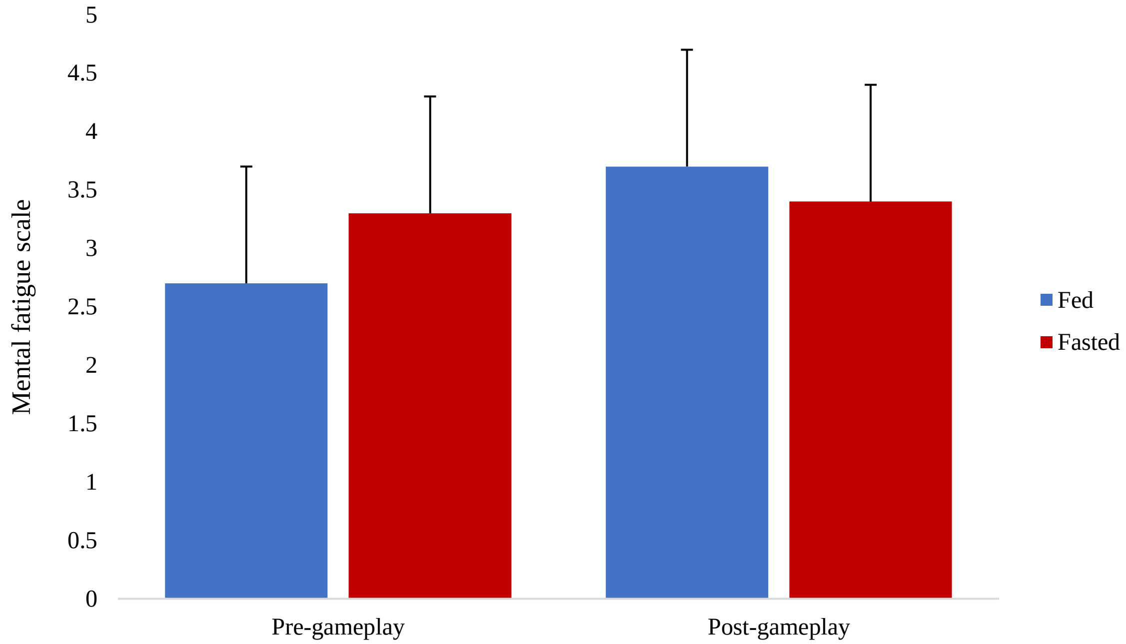

Figure 3 - Change in Mental Fatigue. Values represent mean ± standard deviation. Changes between visit and/or time were not significant (p > 0.05).

Effects of Glucose on Aim Hero Performance

Paired sample t-tests were conducted on performance statistics across each separate game variant (classic, reflex, simple, and time trial) comparing them between sessions (fed/fasted). All four modes measured total shots, targets hit, accuracy, time per hit, and score. Classic and time trial also measured total time within the game variant. The t-tests showed no statistically significant change ($p > 0.05$) between fed vs. fasted visits in the Aim Hero performance.

Table 3 - Aim Hero Classic Performance Statistics

Variable	Fed	Fasted
Total Shots	166.3 ± 41.1	156.9 ± 42.5
Targets	147.0 ± 35.7	139.0 ± 39.3
Accuracy (%)	93.3 ± 14.4	87.8 ± 4.0
Time Per Hit (s)	0.536 ± 0.078	0.542 ± 0.077
Score	108,200 ± 26,300	99,300 ± 34,400
Time (s)	86.3 ± 10.1	82.1 ± 12.2

Values represent mean ± standard deviation. Changes between visit type were not significant (p > 0.05).

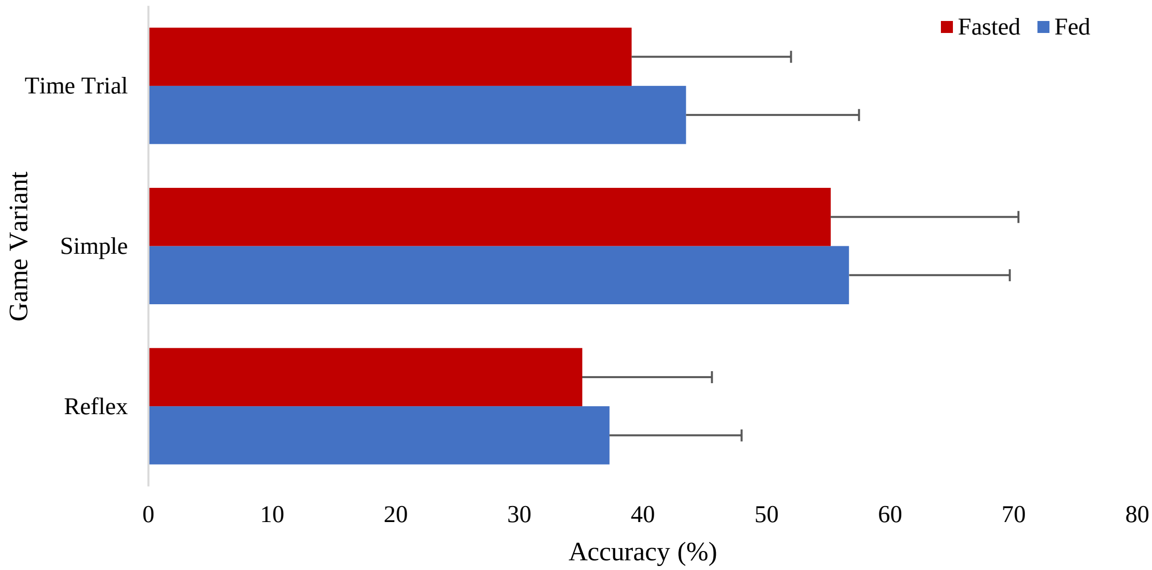

Figure 4 - Accuracies Across Game Variants within Aim Hero. Mean accuracy (percentage of shots that hit the target) ± standard deviation in each game variant (excluding classic). Changes in accuracy performance between visit type were not significant (p > 0.05).

Effect of Glucose on osu! performance

Paired sample t-tests were conducted on each performance statistic from the three separate beatmaps (Megalovania, Blue Zenith, Everything Will Freeze) used within *osu!*. While each of these beatmaps contained a different sequence of targets and music track, they all offered the same performance statistics categories (Table 4) (score, targets missed, largest combo, accuracy, error pre, error post, unstable rate). Accuracy is a percentile measurement of a player's ability to hit objects on-time. The error pre and error post values represent the mean amount of time in which the participant either clicked the target too early (error pre) or too late (error post). The unstable rate is the standard deviation of hit errors multiplied by ten which represents the consistency of a participant's timing for hits. No performance statistics within *osu!* showed significant change (p > 0.05) between the two visits (fed vs. fasted).

Table 4 - osu! Megalovania Performance Statistics

Variable	Fed	Fasted
Score	260,700 ± 256,700	181,200 ± 92,800
Misses	9.7 ± 11.3	11.8 ± 11.1
Combo	119.3 ± 68.5	102.7 ± 53.1
Accuracy (%)	82.3 ± 7.7	80.1 ± 8.7
Error Pre (ms)	-46.4 ± 13.7	-49.6 ± 13.3
Error Post (ms)	46.5 ± 6.7	44.1 ± 10.7
Unstable Rate	534.8 ± 93.9	558.2 ± 109.7

Values represent mean ± standard deviation. Changes between visit type were not significant (p > 0.05).

Effects of Glucose on Enjoyment Level

Paired sample t-tests showed no statistically significant change ($p > 0.05$) in enjoyment level at the end of the two sessions (fed vs. fasted).

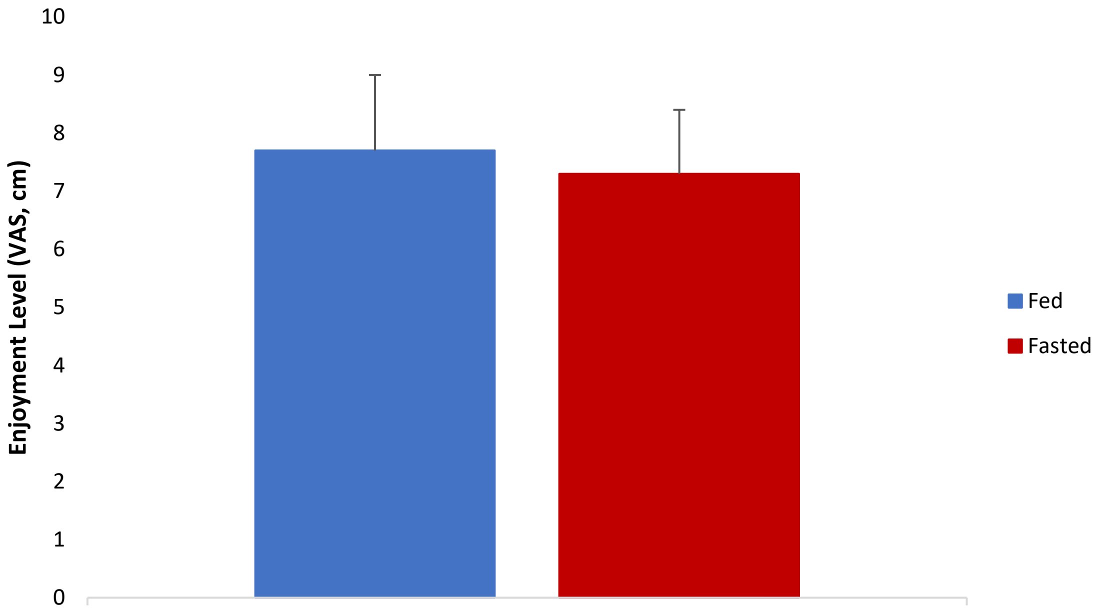

Figure 5 - Enjoyment Level of Each Session. Values represent mean ± standard deviation. Changes between visit type were not significant ($p > 0.05$).

Discussion

The aim of this study was to determine if blood glucose levels affected performance in esports. The results of this study demonstrate that the consumption of glucose (21g) 60 minutes prior to playing the two esports training programs Aim Hero or *osu!* failed to improve performance across the recorded variables. This lack of improvement occurred despite increases in blood glucose levels for the fed session and a decrease in circulating blood glucose between the pre and post measurements of both the fed and fasted trials (Fig. 2).

Increased levels of circulating blood glucose at the initiation of a task allow the brain to devote more energy to high cognitively demanding tasks and subsequently increases performance (6,7,10,17). Within multiple paradigms, researchers have shown that significant decreases in glucose over the duration of the test is correlated to its cognitive load, as well as the performance increments derived from heightened glucose reserves (6). Improved cognitive performance with glucose administration (20-50g at 0-120 minutes prior) occur in a wide variety of both memory-based tasks as well as non-mnemonic tasks including reaction time, word list recall, the Brown-Petterson test, special memory tasks, rapid visual information processing, the Stroop Paradigm, Porteus Mazes, driving simulations, face recognition, serial sevens, water jars tests, as well as several others (6–8,10,17,18).

Similar changes in blood glucose levels between and within the fed and fasted sessions were observed in comparison to other documented high cognitive demand tasks (6,10,19). Given that the blood glucose levels in this study followed this similar pattern (Fig. 2), it is possible that the training programs Aim Hero and *osu!* potentially elicited a high cognitive load to the participant. This is demonstrated by the mean participant glucose levels which decreased significantly by ~18.9 mg/dL (fed) and ~7.2 mg/dL (fasted) between the pre and post-measurements of each respective session (Fig. 2). Future research could potentially examine these changes in blood glucose in a variety of esports session durations rather than the one-hour session utilized, plausibly providing insight as to meal timing to optimize performance while also minimizing the effect of mental fatigue on the esport participant given the high number of hours reported gaming each week. Due to the mean number of esports hours per week (18.9 ± 14.3 hours; Table 1), gamers likely spend more than one hour engaging in esports per day. Due to the likelihood of high cognitive demand for both tasks within this study, the resulting lack of improved mean performance was unexpected, but there are several other factors to potentially explain this occurrence.

In conjunction with mental fatigue, the participants' enjoyment level was recorded at the end of each session. The mean enjoyment level of participants was higher for the fed session but not by a significant amount (Table 5). The results reported here are in agreement with Owens et al. (5) in respect to a statistically significant increase in mental fatigue following completion of assigned computer game task in fed (50g glucose) and fasted trials. However, Owens et al. (5) observed no increase in irritability or other negative factors of mood upon test completion in either session. It should be noted the authors recorded mood/mental fatigue 15 minutes after consumption (immediately prior to beginning computer task) and 20 minutes later upon completion of a computer game (5). Additionally, the nature of the tests within this study lends itself to higher enjoyment levels given that both training programs were also designed to be enjoyable for the user.

Although many cognitive testing modalities showed improvements associated with high blood glucose concentrations, alternative cognitive tests produced contrasting results. These tests include logical reasoning, embedded figures, verbal fluency, and simple reaction time (7,18). Despite the importance of reaction time in both esports training programs (Aim Hero and *osu!*) utilized in the current paradigm, caution should be used when comparing the current results to Owens et al (5). The esports programs are much more complex, comparatively, to the reaction time test used in the previously mentioned literature (5). Owens and Benton (18) tested the speed in which an individual could discern which of two strings were longer and upon completion of that observation pressed a key corresponding to the longer line. Therefore, the added mechanical requirements of aiming at each target as well as their randomized locations in the case of Aim Hero or presented according to a rhythm in *osu!* and esports actions are likely to be considered complex reactions.

The number of mechanical actions required in each of these programs is lower than the average of many esports games. The actions per minute (APM) varies based on the specific type of game, but the most mechanically demanding esports titles such as StarCraft II have players averaging 300+ APM (20). The mean number of shots fired within the classic mode using the Aim Hero platform was approximately 120 per minute. Similarly, the number of actions in the fastest *osu!* song included in the protocol (Everything Will Freeze) was approximately 121 per minute when considering the average difficulty level. Given that the song difficulty level within *osu!* was calibrated to each specific participant, the most advanced participants played at a rate of approximately 200 APM. This speed is more representative of the mechanical input in professional esports. However, only 2 of the 10 participants were skilled enough to perform at this level. Utilizing elite esports players within a live esports setting would give the most practical results representing the effects of glucose on esports performance.

Limitations

It is also important to consider that there is a difference between the esports training programs used within this study and the typical esports modes used during competition. Aim Hero and *osu!* offer a large number of performance statistics granting a greater insight into specific controllable elements of performance (Tables 3 & 4). However, these platforms do not include the player versus player element that is present within all major esports, which greatly subtracts from the intensity of the experience. However, this eliminated the unpredictable nature of online games as a confounder in examining the impact of meal timing. Potentially, researchers could combine competitive esports with interspersed esport training platforms as controllable standard lab metrics. Increased esports session duration (>1-hour) might increase the ecological validity of the investigation as it would more adequately mimic tournament settings and/or practice schedules (~10 hours). However, glucose levels peak after eating typically occur at 1-hour and then progressively return to premeal levels within 2-3 hours. Potentially, shorter protocols may be advantageous for elucidating meal timing within esports during an esports training session. Another potential explanation for the lack of statistical significance, when comparing fed to fasted visits, is the nature of the measurements. For example, while the mean accuracy difference of +5.5% (during the fed visit) for the classic game variant of Aim Hero (Table 3) does not reach the set statistical significance of $p < 0.05$, it does, however, show a very sizable increase when framed from an esports perspective. In fact, the average accuracy of the winner of a CS:GO tournament was 79.0%, while the compiled averages for the 4-8 places were 77.39% (13). Thus, it is important to consider that the number of participants for this study ($n = 10$) was relatively small, reducing the statistical power of this investigation. It is possible that the changes in esports performance would have achieved statistical significance if a larger sample size was utilized.

Conclusion

Despite not finding significant impact from glucose levels on performance, the relationship between blood glucose concentration and esports performance should continue to be explored to provide more insight within this paradigm. Future investigations are necessary to determine the influence of the duration of the rest period following glucose consumption until the start of the esports session. Additionally, the duration of the gaming protocol could be altered to determine the impact of glucose on esports performance, assuming it exists, over time (> 1 hour). Lastly, investigations could explore the current paradigms using a more specific population of esports players.

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Conflicts of Interest

The authors are not aware of any affiliations, memberships, funding or financial holdings that might be perceived as affecting the objectivity of this manuscript.

References

1. Hamari J, Sjöblom M. What is eSports and why do people watch it? Internet Res. 2017;27(2):211–32.
2. Wu Y. The possibility analysis of Esports becoming an Olympic sport. 2019;
3. Hallmann K, Giel T. eSports – Competitive sports or recreational activity? Vol. 21, Sport Management Review. Elsevier Ltd; 2018. p. 14–20.
4. Jenny, S. E., Manning, R. D., Keiper, M. C., & Olrich TW. Virtual (ly) Athletes : Where eSports Fit Within the Definition of " Sport ." 2017;69(1):1–18.
5. Owens DS, Parker PY, Benton D. Blood glucose and subjective energy following cognitive demand. Physiological Behavior 1997;62(3):471–8.
6. Scholey AB, Harper S, Kennedy DO. Cognitive demand and blood glucose. Physiol Behav. 2001;73(4):585–92.
7. Donohoe RT, Benton D. Cognitive functioning is susceptible to the level of blood glucose. Psychopharmacology (Berl). 1999;145(4):378–85.
8. Benton D, Parker PY. Breakfast, blood glucose, and cognition. Am J Clin Nutr. 1998;67:772S-778S.
9. Feldman J, Barshi I. The Effects of Blood Glucose Levels on Cognitive Performance: A Review of the Literature. Pyshcology. 2013;
10. Kennedy DO, Scholey AB. Glucose administration, heart rate and cognitive performance: Effects of increasing mental effort. Psychopharmacology (Berl). 2000;149(1):63–71.
11. McNay EC, McCarty RC, Gold PE. Fluctuations in brain glucose concentration during behavioral testing: Dissociations between brain areas and between brain and blood. Neurobiol Learn Mem. 2001;75(3):325–37.
12. Bejjanki VR, Zhang R, Li R, Pouget A, Green CS, Lu ZL, et al. Action video game play facilitates the development of better perceptual templates. Proc Natl Acad Sci U S A. 2014 Nov 25;111(47):16961–6.
13. Talan A. An impact of esports on cognitive abilities. Click Storm. 2019;(May).
14. Gentile DA. Video Games Affect the Brain—for Better and Worse [Internet]. Dana Foundation. 2009. Available from: https://www.dana.org/article/video-games-affect-the-brain-for-better-and-worse/
15. Carpenter N. Gamers with godlike reflexes are racing to break world records in this rhythm game | PC Gamer [Internet]. PC Gamer. 2019 [cited 2020 Nov 9]. Available from: https://www.pcgamer.com/two-teens-are-on-a-crazy-world-record-race-in-extremely-challenging-rhythm-game-osu!/
16. Webb K. Professional gamers like Ninja use this music game to practice their aim and improve their mouse skills - Here's how you can play for free [Internet]. Business Insider.

2019. Available from: https://www.businessinsider.in/professional-gamers-like-ninja-use-this-music-game-to-practice-their-aim-and-improve-their-mouse-skills-heres-how-you-can-play-for-free/articleshow/70819778.cms#:~:text=%22Osu!!%22 is a free,and improve their mouse skills.

17. Smith A, Kendrick A, Maben A, Salmon J. Effects of breakfast and caffeine on cognitive performance, mood and cardiovascular functioning. Vol. 22, Appetite. 1994. p. 39–55.
18. Owens DS, Benton D. The impact of raising blood glucose on reaction times. Neuropsychobiology. 1994;30:106–13.
19. Fairclough SH, Houston K. A metabolic measure of mental effort. Biol Psychol. 2004;66(2):177–90.
20. LeJacq Y. How fast is fast? Some pro gamers make 10 moves per second [Internet]. NBC News. 2013. Available from: https://www.nbcnews.com/technolog/how-fast-fast-some-pro-gamers-make-10-moves-second-8C11422946