PHD DISSERTATION

THESIS SUMMARY

OLIVER SZABELLA

The relationship between physical activity and e-sports performance

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Eötvös Loránd University, Faculty of Education and Psychology

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THEORETICAL BACKGROUND

1. The Relevance and Objectives of the Research

The research focuses on sports education within educational sciences, specifically in an area that is one of the most popular leisure activities among young people: the video game industry (Czakó et al., 2023). Video gaming, or "gaming," has developed to such a high level over the years that there are players who pursue this pastime as a means of earning money, thus qualifying them as professional athletes. These individuals are referred to as e-sports players. Although the activity's status as a sport is questionable, as it lacks some traditional physical components, it shares many attributes with traditional sports (Jenny et al., 2016). As e-sports gain popularity, sometimes surpassing the viewership of traditional sports (Lynch, 2017), the industry is becoming increasingly professional. If we accept e-sports as a sport, understanding that the competition occurs primarily on a mental level, it would be the only team sport where physical activity is not dominant. Magistretti's (2015) research reveals that our brain is responsible for about 20% of the calories burned under general exertion, highlighting mental endurance as a key attribute for professional gamers. This research aims to examine how mental fatigue can be observed during gaming, whether it can be documented, and whether physical activity can influence this process.

2. The Relationship Between E-sports and Sports

Since 2010, researchers have been investigating whether e-sports can be considered a sport (Jonasson & Thiborg, 2010; Lee & Schoenstedt, 2011; Kane & Spradley, 2017). The connection between e-sports and traditional sports, as well as the defining characteristics of e-sports, serves to strengthen e-sports' role as a sports entertainment product. While physical activity is not the dominant factor, other traditional sports also exhibit minimal physical activity (Hallman & Giel, 2017).

The world of video games, similar to traditional sports, can be divided into two main areas: "gaming" and "e-sports." These two distinct subsets can be paralleled with the traditional sports

analogy of "recreational sports" and "competitive sports." It is essential to differentiate between the two, as their comparison reveals different characteristics, leading to varied research possibilities (Szabella, 2018).

Figure 1: Characteristics of e-sports and sports (source: Szabella, 2018)

3. Examination of E-sports from a Physiological Perspective

E-sports activities require mental abilities such as concentration, stress tolerance, and various cognitive skills that influence e-sports performance. Cognitive abilities like multitasking, memory, and spatial awareness are crucial (Ding et al., 2018). Physical activity combats depression and anxiety, leading to a better quality of life, improved cognitive function, and better sleep quality (Taylor, 2022).

If we accept that physical activity influences mental abilities, particularly concentration and stress tolerance (Ludyga et al., 2020; Toth et al., 2020), and that mental abilities correlate with e-sports performance (Andre et al., 2020; Toth et al., 2019), the question arises as to how physical activity affects e-sports performance.

3.1. E-sports from a Mental Perspective

Beyond Ding et al. (2018), several studies have examined the mental demands within e-sports. Various mental skills have been identified, such as anxiety management, sustained attention,

and emotional self-regulation, which competitive players use to enhance their performance (Himmelstein et al., 2017). Similar to traditional sports (Lazarus, 2020), emotions can also impact a player's performance (Behnke et al., 2022). Toth et al. (2020) identified key abilities in action video games, including task-switching, information processing, attention, and memory.

Stress is also emerging as an issue in relation to esports, which is supported by several studies. One study, for instance, reported an increase in anxiety levels among winners, as well as elevated cortisol levels from baseline to post-game states. Additionally, two studies observed the activation of the sympathetic nervous system (Leis and Lautenbach, 2020). During an esports competition, where players must perform under stress, they exhibit higher heart rates (Valladão et al., 2020), and after the competition, their mental fatigue levels increase, further confirming the mental strain of esports (Andre et al., 2020). It also matters whether the opponent is a computer program or another human; in the latter case, a higher heart rate is observed (Watanabe et al., 2021).

3.2. E-sports from a Physical Perspective

E-sports activities are performed while seated, and a sedentary lifestyle negatively affects the human body. It increases the risk of cardiovascular diseases, cancer, metabolic disorders, and musculoskeletal conditions such as joint pain and osteoporosis. Additionally, a sedentary lifestyle is linked to depression and other cognitive impairments (Park et al., 2020; Cantrell et al., 2023). A study investigating the negative effects of prolonged sedentary activity found that breaking two hours of gaming with a six-minute walk resulted in 70% of participants reporting an improvement in their e-sports performance (DiFrancisco-Donoghue, 2021).

While heart rate increases during e-sports activities similarly to physical exercise, energy consumption does not rise, and blood glucose levels increase, unlike in physical exercise, where glucose levels decrease (Haupt et al., 2021). First-person shooter (FPS) games induce greater peak heart rate changes compared to multiplayer online battle arena (MOBA) games (Sousa et al., 2020).

E-sports players believe that a healthy lifestyle and proper time management can enhance their performance, indicating that further research is needed to examine the impact of physical

exercise not only on cognitive functions but also on specific e-sports performance characteristics (Sharpe et al., 2023).

Professional e-sports players are more likely to lead physically active lifestyles and exceed the physical activity guidelines recommended by the World Health Organization (WHO) (Voisin, 2022; Trotter et al., 2020). These professionals spend over five hours a day practicing, with about one hour dedicated to physical training, and more than half of the players believe that physical training positively affects their performance (Kari & Karhulahti, 2016; Kari et al., 2019).

4. The Relationship between E-sports Performance and Physical Activity

Research on the impact of physical activity on e-sports is still in its early stages, often borrowing ideas and practices from traditional sports research (Leis et al., 2021). Physical activity is an invaluable source of physical and mental health and is directly and indirectly related to the quality of performance in e-sports players (Kocić et al., 2022).

A summary study revealed that individual performance indicators such as reaction time, response time, keyboard skills, and mouse control are important performance factors that correlate with match outcomes, and these skills improve with more time spent playing (Sanz-Matesanz et al., 2023).

Exercise improves cognitive functions (Ludyga et al., 2020; Wilke et al., 2019) and mental well-being (Lubans et al., 2016; Schuch et al., 2016). However, few studies have examined how exercise affects mental well-being or cognitive functions within e-sports performance.

One study applied High-Intensity Interval Training (HIIT) intervention 20 minutes before gameplay, resulting in a 75% increase in attack accuracy and a 9% increase in target elimination in a specific League of Legends game test (de Las Heras, 2020). Another study compared the effects of walking, continuous gaming, and rest on e-sports performance from both objective (in-game data like K/D ratio or W/L ratio) and subjective (players' perceptions) perspectives. While there were no significant differences in objective terms, a weak but positive relationship was found in subjective terms, with players feeling that walking was the most effective way to boost performance (DiFrancisco-Donoghue, 2021).

Higher cardiorespiratory fitness and reaction time are significantly correlated among e-sports players, suggesting that players with better cardiorespiratory fitness are faster and more accurate (Dykstra et al., 2021).

In summary, existing studies do not show clear results regarding the effects of physical activity on e-sports performance. The consensus mainly lies in the attitudes and motivation of e-sports players toward exercise, as most players believe that exercise benefits their performance. However, the limited research on this topic warrants caution in drawing definitive cause-and-effect conclusions (McNulty et al., 2023).

METHODOLOGY

1. Structure and Logic

Following the theoretical background, we defined several questions and conducted various studies to comprehensively analyze the topic. We categorized our studies into two areas (sports education and sports science) and established long-term, medium-term, and short-term time frames for easier structuring. Using a visual map, which is also included in the full PhD dissertation, we can graphically illustrate the structure of the work (Figure 2).

We conducted four experiments in total. After the introductory research (1), the experiments were divided into sports education (1) and sports science (2) categories (see methodology sections 2, 3, 4, and 5). The structure and methodology of the dissertation involve discussing the completed research and experiments in separate chapters after the introduction and literature review. In this summary, we proceed similarly, first detailing the methodology of each of the four studies in the methodology chapter. The order, which will also be maintained in the following chapters, is: Introductory research, Long-term research, Medium-term research, Short-term research.

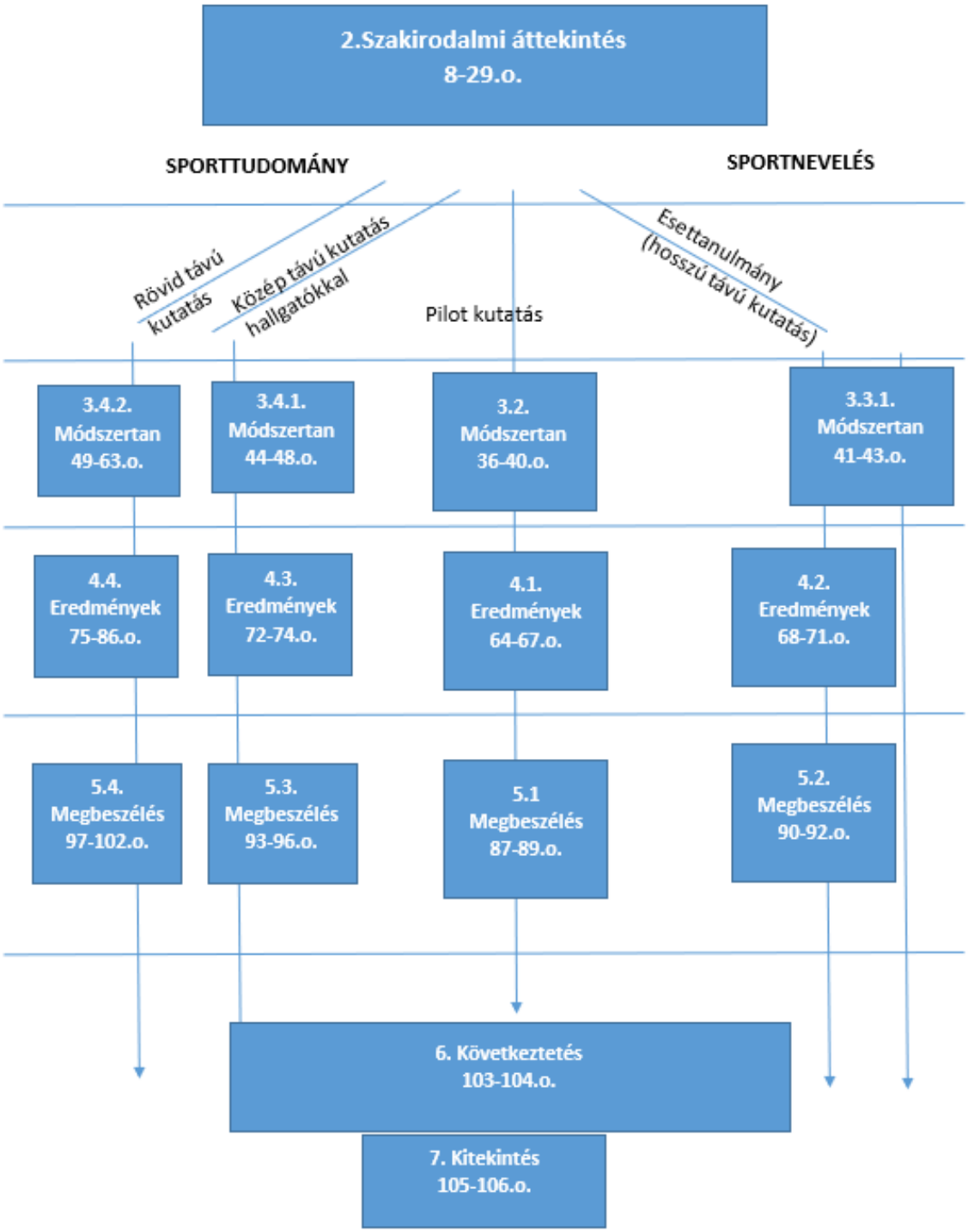


Figure 2: Visual Table of Contents (source: Szabella Olivér: The Relationship between Physical Activity and E-sports Performance, PhD Dissertation)

2. Pilot study: Methodology

This study aimed to observe whether implementing the basic pillars of a healthy lifestyle in the life of a Hungarian professional player (at the T3 level on the international ladder) would lead to visible, objective performance changes.

Some e-sports players have irregular sleep patterns and poor eating habits (Wattanapisit et al., 2020; Chan, 2022; Yin et al., 2020). A large percentage are inactive and do not engage in physical activity at all (Trotter et al., 2020).

We needed to find a player in the Hungarian T3 environment who met the above characteristics and was willing to undergo lifestyle changes for the research. Preliminary inquiries were made through personal contacts, thanks to the Hungarian professional e-sports background, and an in-depth interview was conducted to uncover general lifestyle habits.

Based on the in-depth interview and literature analysis, we defined three basic pillars of lifestyle changes to be implemented in the player's life: a regular and consistent sleep pattern, a diet guided by a nutritionist, including three mandatory daily meals, and a physical training plan executed three times a week with the help of a personal trainer.

From the perspective of e-sports performance, two objective data points were defined: the K/D ratio[1] during ranked matches, indicating the total number of "points" the player earns or loses for the team, and the win ratio (WR[2]) during ranked matches, which encompasses more complex problem-solving abilities, communication, and stress tolerance, as it is a team game where individual performance is not the only factor. We did not specify the number of matches to be played, instructing the participant to play as much as they usually do.

The research lasted for two months, from January 1 to March 1, 2020. In the first month, we monitored the two defined performance metrics (WR and K/D) without any lifestyle changes, and in the second month, we implemented the three healthy lifestyle elements and monitored the same variables.

[1] From the english words „kill/death”
[2] From the english words WinRate

Additionally, we measured physical condition changes using an InBody720 body composition analyzer before and after the experiment, and mental strength changes through questionnaires, focusing on the state of "burnout."

3. Long-term Research – Sports Education: Methodology

We conducted a case study involving one of Hungary's top-level e-sports players with the most achievements. The study aimed to examine the potential for changing the mentality and approach to sports of a professional T1–T2 player with the help of a mentor who embodies sports values and sets an example through their appearance and behavior (Zhao, 2015).

We sought out a Hungarian player through personal contacts who held a professional contract internationally at the T2 or T1 level and whose main source of income was e-sports. It was also important that physical activity and exercise were not part of their life, and they held a negative mentality towards sports at the beginning of the research.

According to our vision, the values represented by sports can be conveyed to an internationally competitive e-sports player through a sporty mentality and exemplary behavior. The statement we have formulated in this regard is as follows:

1. *A Hungarian e-sports player with outstanding achievements can also be educated in sports and can be instilled with values related to sports, such as a love for physical activity, perseverance, and handling defeats, through exemplary behavior and a close mentoring relationship.*

The goal was to introduce physical activity into the player's life and change their mentality. Changes in the player's mentality and responses were examined through their social media communication over the four-year research period.

We also interviewed other Hungarian professional (T3-level) players who encountered the same mentor and made notes based on their responses about the healthy e-sports mindset.

4. Medium-term Research – Sports Science: Methodology

We conducted an experiment in which university students were invited to participate in a medium-term ranked e-sports competition with a control group. The students were divided into two groups: a physical activity (PA) group and a control group. The research aimed to examine

the differences between the two groups' results in a selected game's ranked competition, with all other conditions remaining constant. The research was conducted anonymously, with no identifying information collected.

The first task in designing the research was to ensure equal conditions for all participants. Therefore, the preliminary questionnaire included a question to determine what e-sports games the participants had played and which they had never tried.

After a market analysis, we targeted a newly released game that met all the criteria for an e-sports title (Szabella, 2018) and was freely available. The selected e-sports title was "The Finals."

Once the number of participants (n=21) was determined, we divided them into two groups. One group was named the physical activity (PA) group, and the other the control group. Group allocation considered potential sports obligations, so those who indicated they were certified or national athletes could only be placed in the PA group.

The groups were divided to ensure that both groups had an equal number of trained participants, as much as possible.

In-game, both groups were required to play 20 ranked matches within a week. The physical activity group had to engage in 30 minutes of cardio exercise (running or cycling) four times a week and document it, while the inactive (control) group could not engage in any exercise and had to document this as well.

The research examined the expected results versus the actual results within the context of the two different groups, as well as the perceived task difficulty on the BORG scale.

Communication took place on an online messaging and communication platform, Discord, and daily administration was handled by each participant via a shared Google Drive folder.

Two hypotheses were formulated for the research:

1. *The physical activity group will achieve better results in the ranked competition under the same conditions as the control group.*
2. *According to the BORG Scale, the control group will find the task more difficult from week 6 to week 12 than the physical activity group.*

5. Short-term Research – Sports Science: Methodology

This experiment aimed to examine whether physical activity interventions during e-sports performance-focused tests result in performance improvement or decline and whether this is reflected in graphs recorded by a portable EEG device. Since we know that physical activity positively affects cognitive functions, and some cognitive functions are necessary for good e-sports performance, it is a logical assumption that physical activity could have real-time effects on e-sports performance or its components.

We tested this hypothesis by applying a specially developed research model. The method consisted of two parts: a preliminary measurement and an e-sports-specific measurement.

During the preliminary measurement, we established the baseline for the subjects, asking about their time spent playing, demographic data, and sports habits. Additionally, we performed a VO2 max test to assess their cardiovascular system's condition. The subjects also completed a STROOP test while wearing an EEG device, during which we examined the mental fatigue reflected in the brainwave graphs.

The second examination focused on specific e-sports mechanical skills identified in the literature, combined with a physical activity intervention. The test consisted of four blocks, each containing the same tasks (see section 5.1: E-sports-specific test descriptions). The first two blocks were completed without a break, followed by a rest between the second and third blocks, and then physical exercise (HIIT) between the third and fourth blocks, with the subjects continuously wearing the EEG device.

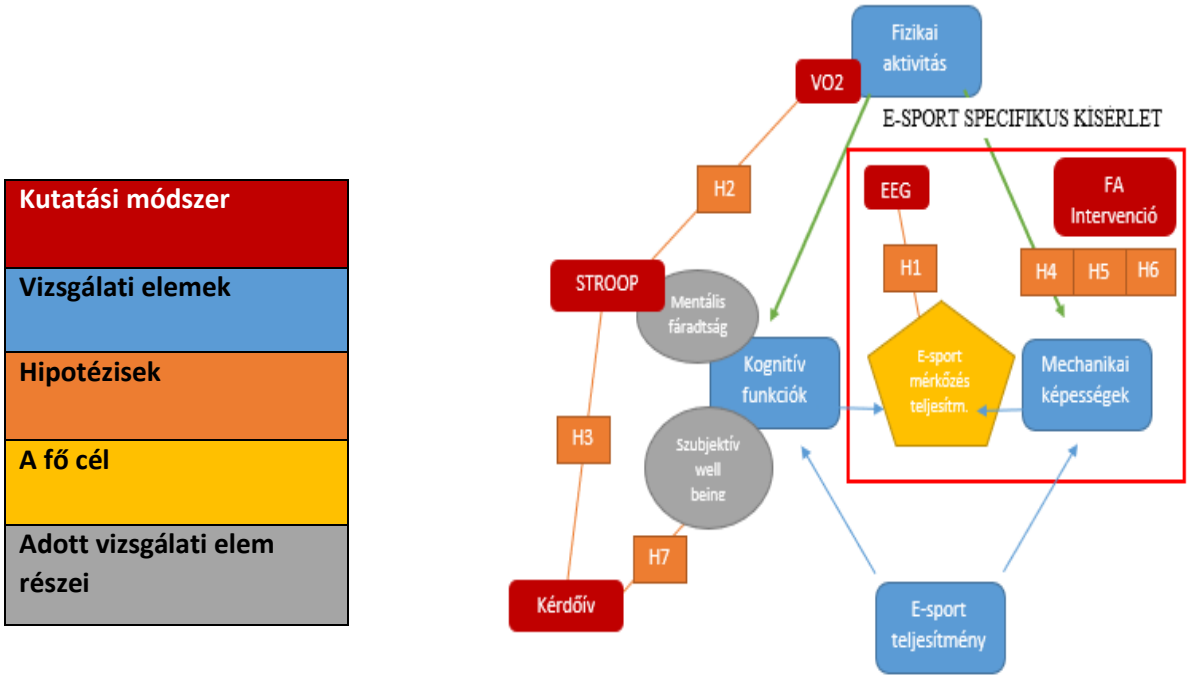
The experiment was conducted offline and took approximately 360 minutes from arrival to departure, with a total of 12 participants. A strict protocol was followed between the two test parts, including a break (see section 5.2: Break protocol).

Participants had to meet the following criteria:

- Plays or has played a MOBA or FPS game
- Competed at T1, T2, or T3 levels with a contract

- Previously competed at T1, T2, or T3 levels but is now retired
- Agrees not to consume stimulants like caffeine or other psychoactive substances at least 4 hours before the test

These studies may have revealed how brain waves indicating mental fatigue change in real time as a result of physical activity. We could learn how individuals who are more physically active or have better cardiovascular systems respond to the onset of mental fatigue. Ultimately, we could see whether any changes in brain waves or performance indicators could be detected. This is illustrated in the research design graphic below, explained with color codes.



Ábra 3.: Kutatási dizájn grafika, 2023 (saját szerkesztés)

In order to answer the research questions above, the following hypotheses were formulated and examined in the dissertation:

1. *Mental fatigue can be assessed during e-sports activities using EEG devices by analyzing alpha and theta waves.*

2. *Individuals with better cardiovascular health perform better in mental fatigue simulation tests.*
3. *There is no correlation between the STROOP test and the time spent playing games.*
4. *Mental fatigue that arises during e-sports performance tests can be mitigated through physical activity interventions.*
5. *After a physical activity intervention, players show different EEG activity during e-sports performance tests compared to when no physical activity is performed.*
6. *Physical activity interventions do not impair mechanical abilities in the second phase of the e-sports tests.*
7. *Players' subjective well-being is better during the phase with physical activity intervention than during the control phase.*

5.1 E-sports-specific test descriptions

1. *Reaction Time Measurement*

We used the Human Benchmark online program, which offers a test accessible through a website. In this test, the subject sees a red section on the screen with the message "Wait for green" and must click as soon as the red area turns green. The program immediately displays the result, which the test leader records. Each participant had three attempts, and the average of the three trials was taken as the result.

2. *Visual Memory*

In the visual memory test on the Human Benchmark online program, blue squares appear on the screen, some of which turn white and then blue again. The participant had to click on the squares that had turned white from memory. As the test progressed, more squares appeared on the screen. The test ended after three incorrect clicks. The result was provided by the "level X" in the upper left corner of the screen.

3. *Typing Skill Test*

We tested typing skills using the "Typing test" function in the Human Benchmark online program. Participants were given a text to type on a blue screen. As they typed, correct letters appeared in green, and errors in red. The task was considered successful if the full text was

typed. The result was recorded based on the WPM (Words Per Minute) score after typing the text. Any remaining errors at the end were noted by the research leader.

4. *Mouse Usage Skill Measurement*

The mouse usage skill was tested through the "Gridshot Ultimate" minigame in the Aim Labs program. In this minigame, blue spheres appear on a 3D background, and the participant must click on them as quickly as possible. At any given time, three targets appear on the screen, and when one is hit, a new one appears. The task lasted 180 seconds. The program provided a score that took accuracy, number of targets hit, and missed clicks into account. The research leader also recorded the accuracy displayed as a percentage.

5. *E-sports Game in FPS or MOBA Types*

After the preliminary tests, participants immediately played a full ranked game in their preferred FPS or MOBA game. The game was designed to simulate mental stress, and the game result and the player's individual statistics were recorded. Participants played ranked matches in two types of FPS games (Rainbow 6: Siege, Counter-Strike 2) and one type of MOBA game (League of Legends).

5.2 Break Protocol

Between the preliminary measurements and the e-sports-specific measurements, we provided a minimum 60-minute break, including fresh air, walking, and a meal. After finishing the STROOP test, participants were instructed to get up from their computers and prepare for fresh air, walking, and eating.

The goal of the break was to allow the participants to recover from the mental and physical stress of the preliminary measurements so they could start the e-sports-specific measurement unaffected by previous tasks. Each participant walked the same distance, which was 2 x 600m outdoors, and consumed the same meal. According to the Yazio calorie tracking program, the meal contained 453 calories (29g carbohydrates, 33g protein, 21.8g fat).

RESULTS

1. Pilot Study: Results

The first part of our study focused on in-game performance during the experiment. The results were displayed on graphs (Figure 4).

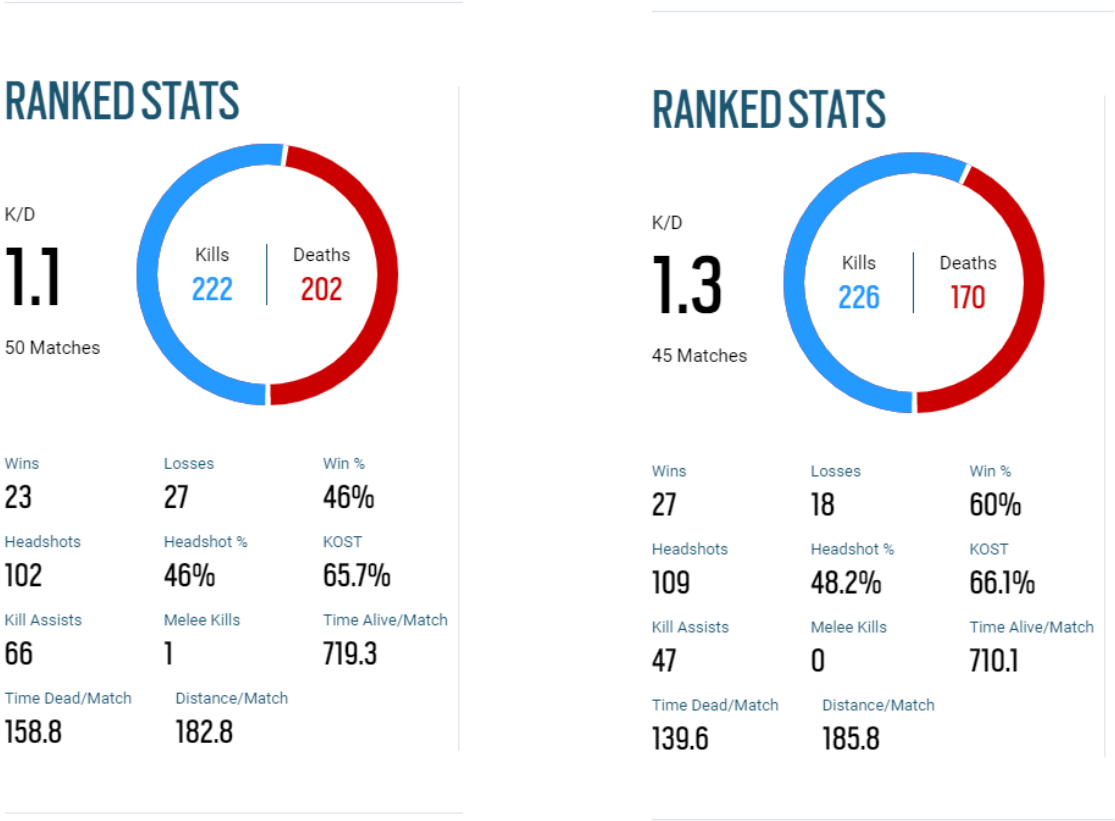


Figure 4: In-game results (K/D and WR) during the first and second phases of the experiment (source: statistics based on tabstats.com)

The two in-game data points examined were the K/D ratio and the WR. The results are clearly visible on the two graphs. In the first month, when there was no lifestyle change (left), the results were 1.1 K/D and 46% WR. In the second month (right), the K/D ratio improved to 1.3, and the WR increased to 60%.

Among the short subjective questions, one of the most important was how many matches the player could play without burning out, i.e., in our interpretation, without becoming so mentally frustrated that they stopped playing.

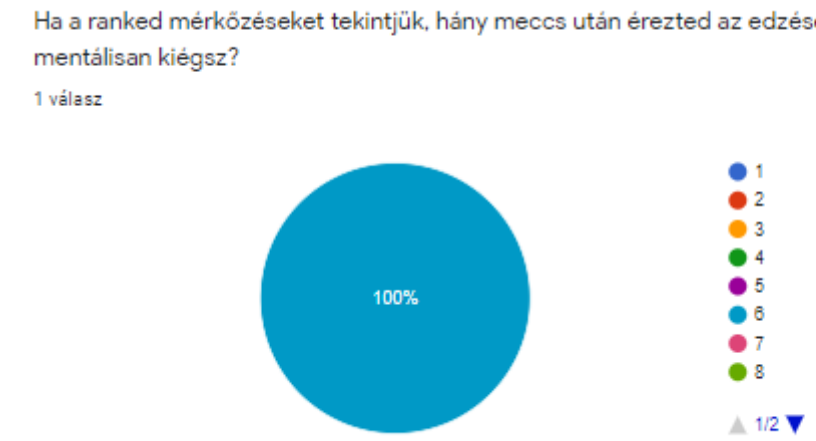


Figure 5: Question about the number of ranked matches before lifestyle changes (source: self-created)

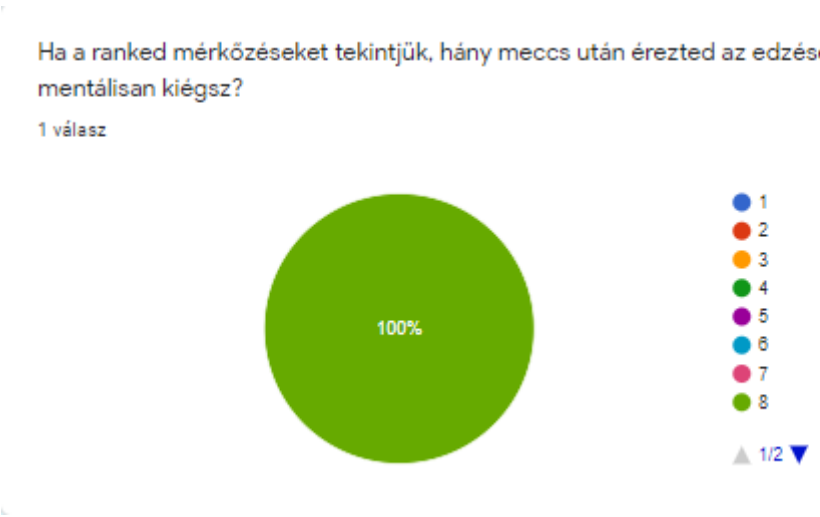


Figure 6: Question about the number of ranked matches after lifestyle changes (source: self-created)

According to the player's feedback, in the first month of the study (Figure 5), they burned out after playing six ranked matches, while in the second month (Figure 6), this number increased to eight ranked matches.

2. Long-term Research – Sports Education: Results

In 2019, at the beginning of the research, the player was a member of the Mad Lions team, competing in the top-tier Spanish League of Legends (LOL) championship. During 2019, the player achieved fourth place in a B[3]-tier tournament and fourth place in an A-tier tournament. The player then transferred to the French league, joining the Gamers Origin team.

In 2020, the player won the French league (B-tier) twice with their team, but the team only reached the 5th-8th position in the European Masters (A-tier). The player left the team after a year and a half but stayed in the French league, transferring to the newly established Team BDS. During this time, the player did not win any championships and did not qualify for the European Masters. After a year, the player left Team BDS and returned to the Spanish league to join Team Heretics. The Team BDS organization purchased a slot in the LEC (S-tier) competition system, but the player was not taken along and continued playing in the Spanish league (B-tier) under the new team name, Los Heretics.

During this period, the player continuously underwent sports education, as evidenced by their social media communication. Screenshots of key points in this communication are included in the dissertation's appendices. The development was divided into four stages: interest phase, failure, breakthrough, and a sporty life with motivating others.

When the professional player first encountered the mentor focused on healthy player methods, they developed an internal interest in the mentor and the ideas represented.

In the next phase, the player sought concrete help in changing their lifestyle. We provided all the necessary tools, including workout plans, diets, and continuous support. However, despite this, the period was marked by multiple setbacks, abandonments, and failure to adhere to plans.

After the previous phase, a breakthrough occurred, with physical activity becoming a daily part of the player's life, which was also reflected in their social media communication. The player often viewed physical exercise as a form of "therapy" and could not imagine their days without regular exercise.

[3] In the full document of the dissertation we use the S-A-B Tier system because of the pictures included instead of the previously introduced T1-2-3 system. The meaning is the same.

What followed was the independent planning, organizing, and spreading of a healthy lifestyle. During this stage, the player independently explored various training methods, tried different diets, and read articles related to healthy living. This period also marked the rise of the "gymbros" nickname in Spain, referring to the player's team, as after their arrival, the entire team began working out together.

Interviews with two other Hungarian professional-level (T3) players also yielded positive results. The responses revealed that they encountered this method during a crucial life stage—the transition to adulthood—making it an opportune time to learn new and positive habits. All interviewees reported receiving significant benefits, and it was revealed that since retiring from their professional e-sports careers, they have continued to lead active lifestyles, with one of them undergoing a complete lifestyle change.

3. Medium-term Research – Sports Science: Results

After the 12-week research period, several interesting direct and indirect results were reported concerning the hypotheses. The uniqueness of the research lies in the fact that the participants were university students with student status, forming the sample that received the preliminary questionnaire. Originally, 21 participants were found suitable and voluntarily agreed to participate in the study, including completing the 12-week administrative tasks. One participant was excluded in the first week due to not meeting the conditions of the preliminary questionnaire. By the 12th week, 14 out of 21 participants completed the study, resulting in a 33% dropout rate. It is also important to note that while 6 participants from the control group failed to meet the requirements, none of the participants from the physical activity (PA) group dropped out.

At the beginning of the study, participants were asked via a questionnaire (see appendix 4 of the dissertation) to estimate the rank they expected to achieve over the 12 weeks. These expectations were then compared to the actual rank achieved at the end of the 12th week.

Among the participants, five had previous gaming experience (three in the PA group and two in the control group). They achieved the highest ranks, with three finishing in platinum and two in gold by the end of the study. The best result was platinum 2, the 15th highest rank out of 20. The control group's average result was gold 4, while the physical activity group's average result was silver 2.

If we exclude the participants with prior gaming experience from both groups, the control group's rank changes to silver 4, and the PA group's rank changes to silver 3.

Regarding the BORG scale results, the following table summarizes the findings:

	BORGk6s	**BORGk6e**	**BORGk12s**	**BORGk12e**
blazeluvsyou*	0	8	0	5
vorosviktoria5164	0	1	0	3
dtas187	0	5	0	7
PIXEL 6750*	0	4	0	7
	BORGpa6s	**BORGpa6e**	**BORGpa12s**	**BORGpa12e**
agardy.peter	6	3	6	7
itznorbi*	8	6	7	9
mestervio	8	7	6	4
TBB555	6	9	6	8
Tomi0114	3	8	2	8
bur_sza	4	7	4	6
MatezzHUN*	2	8	2	8
Ricso5*	5	1	4	1
thekm10	6	2	8	2
vincent_1231	5	7	5	3

Table 1: BORG Scale Results (source: self-created, 2024)

When examining the results of the two groups separately, in the control group, the perceived difficulty of performing the task increased by one full point on the BORG Scale, from 4.5 in the first week to 5.5 in the second week. In the physical activity group (PA), the score was 5.8 in the 6th week and 5.6 in the 12th week, indicating a decrease of 0.2 in the perceived difficulty of the task.

An important takeaway from this research is that it provided many insights regarding the research methodology, the game used, and the fact that the subjects were students.

4. Short-term Research – Sports Science: Results

The study involved 12 participants: 4 professionals, 3 semi-professionals, and 5 retired professional/semi-professional players, with an average age of 23.75 years (minimum 18, maximum 34). The participants had an average of 9,200 hours of gaming experience, with the highest being 15,000 hours and the lowest 3,000 hours. The e-sports titles included two League of Legends players, three Counter-Strike players, and seven Rainbow Six: Siege players.

Out of the 12 participants, the average BMI was 24.93, but with significant variation—the lowest being 16.5, indicating underweight, and the highest being 30.35, indicating overweight. Thus, the average participant was at the upper end of the normal BMI range, but only one participant had a normal BMI of 22.59.

When examining the VO2 max results based on a table in the dissertation (see Table 1), which categorizes fitness levels from very poor to excellent by age group, the overall average for the participants was 37.4 kg/m^2, falling into the poor category for their average age. If we examine the results individually, considering age, the findings are as follows: very poor: 2; poor: 2; okay: 6; average: 2. No participants achieved a better-than-average result[4].

Regarding the IPAQ questionnaire results, three participants reported being inactive, two reported minimal activity, and seven reported engaging in health-preserving physical activity. It is important to note that the questionnaire was self-reported, and participants tend to overestimate their physical activity (Prince et al., 2008; Lee et al., 2011).

4.1. E-sports Performance Results

In all four cycles, the participants' data were compared to their own results as the study progressed. The results were displayed on graphs, with different colors representing the data for different participants (Figures 7-11).

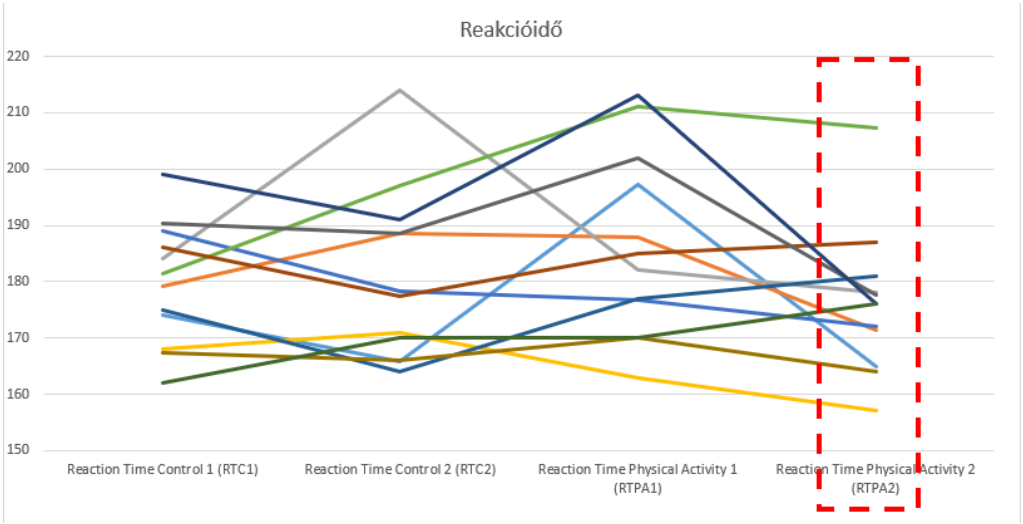


Figure 7: Reaction Time Results (source: self-created)

[4] Based on the normal BMI graph: https://myhealth.alberta.ca/Health/Pages/conditions.aspx?hwid=zm2277

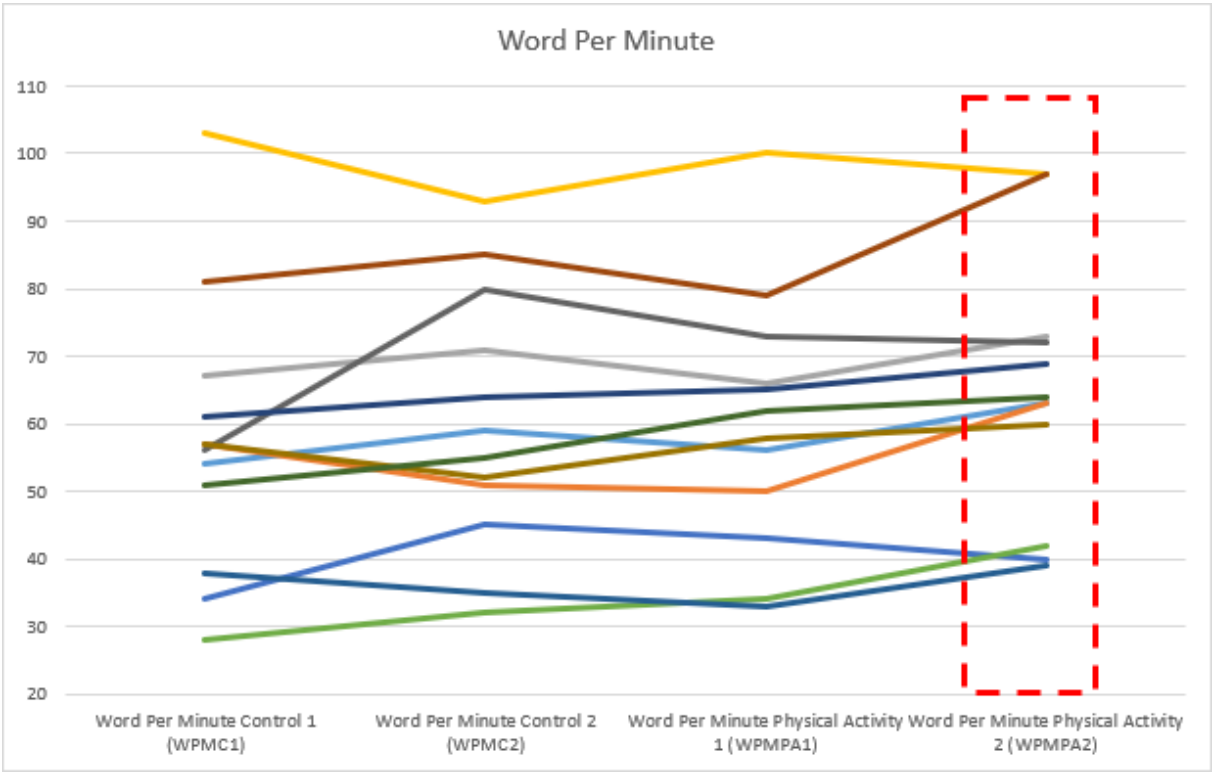


Figure 8: Keyboard Skills Results (source: self-created)

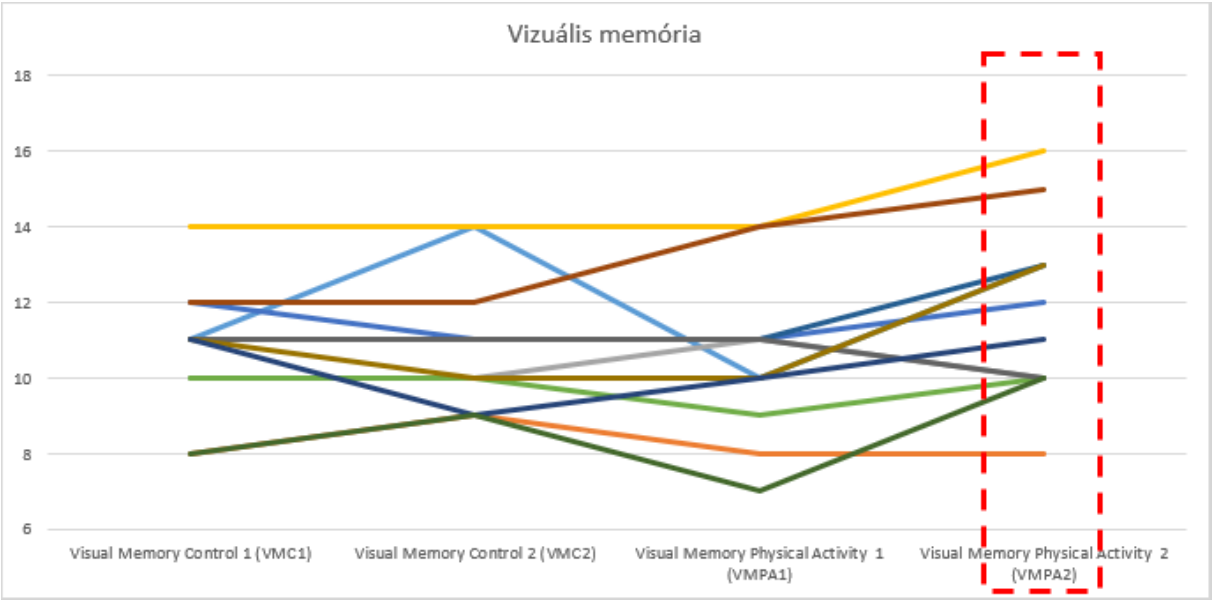


Figure 9: Visual Memory Results (source: self-created)

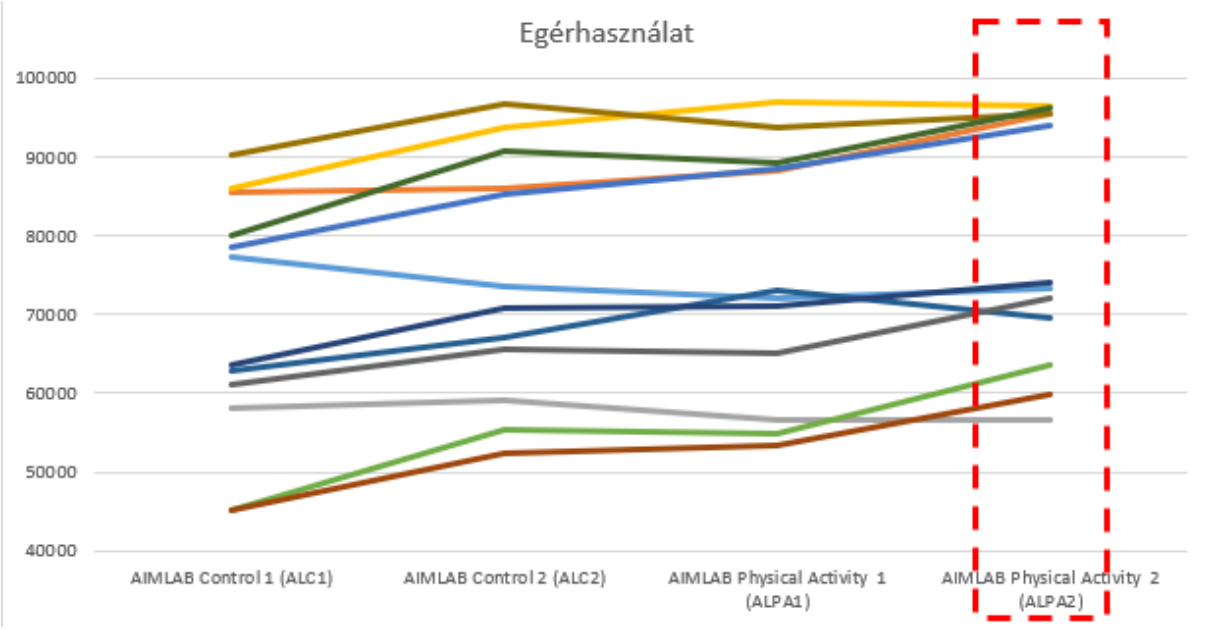


Figure 10: Mouse Skills Score Results (source: self-created)

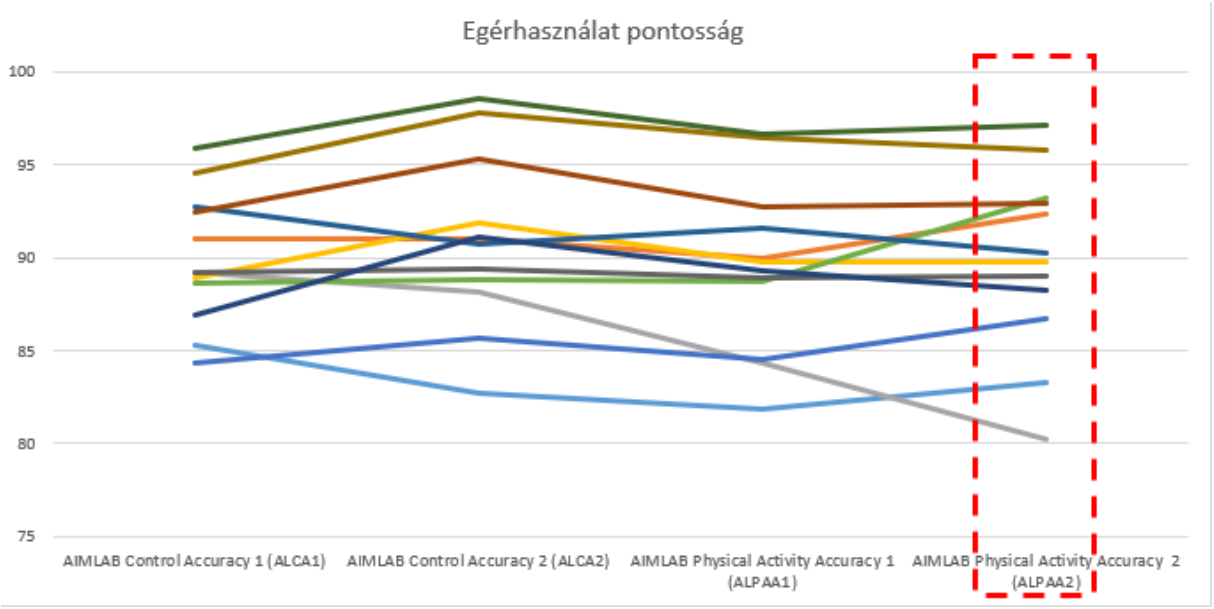


Figure 11: Mouse Skills Accuracy Results (source: self-created)

The general pattern observed in the results is that in the individual skill tests (except for the ranked match), the fourth measurement after the physical activity intervention yielded the best results, despite it being the final measurement, meaning that the players had been mentally taxed for several hours. Regarding accuracy, however, the second measurement was the best, with a score of 90.92, while the fourth measurement fell short by just 0.11 points (Figure 11). Furthermore, the second measurement was better than the first in all tests, and the third

measurement, except for mouse skills score (Figure 10), was worse than the second in all other tests. The mouse skills score showed continuous improvement over time (Figure 10). In terms of percentage change, the improvement between the first and second measurements was 7.4%, between the second and third measurements was 0.69%, and between the third and fourth measurements was 4.9%.

4.2. Portable EEG Graph Results

In reporting the results, we highlight one participant with the best VO2 max score and one with the worst, and compare their data in the STROOP test and the in-game control test (Figures 14-15), as well as before and after the physical activity intervention (Figures 12-13).

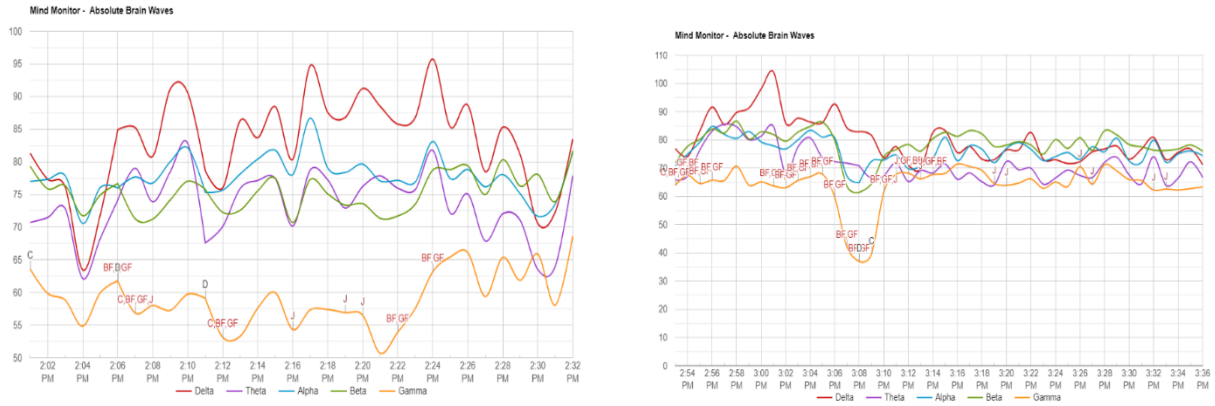


Figure 12: E-sports-specific 3rd and 4th Measurement EEG Graph for the Least Fit Participant (source: self-created)

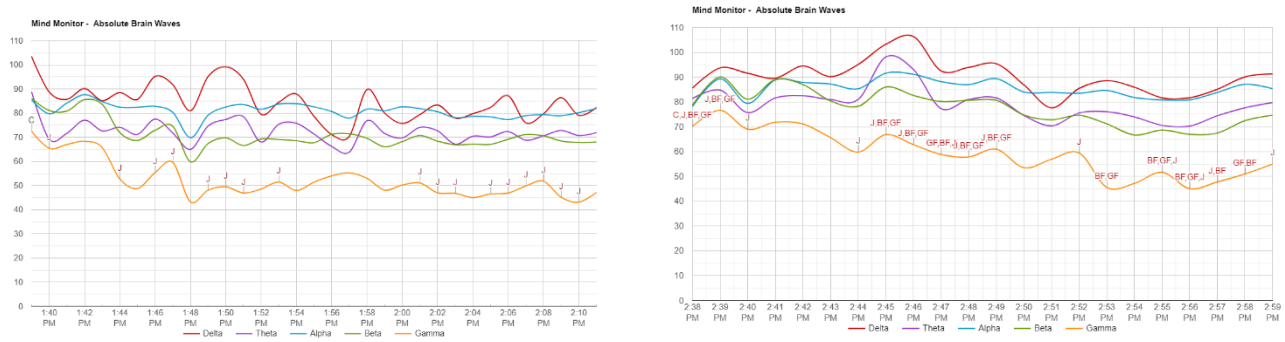


Figure 13: E-sports-specific 3rd and 4th Measurement EEG Graph for the Most Fit Participant (source: self-created)

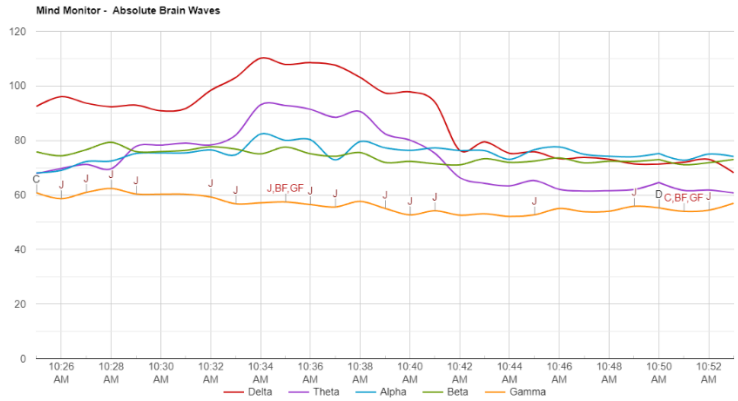


Figure 14: STROOP Test EEG Graph for the Most Fit Participant (source: self-created)

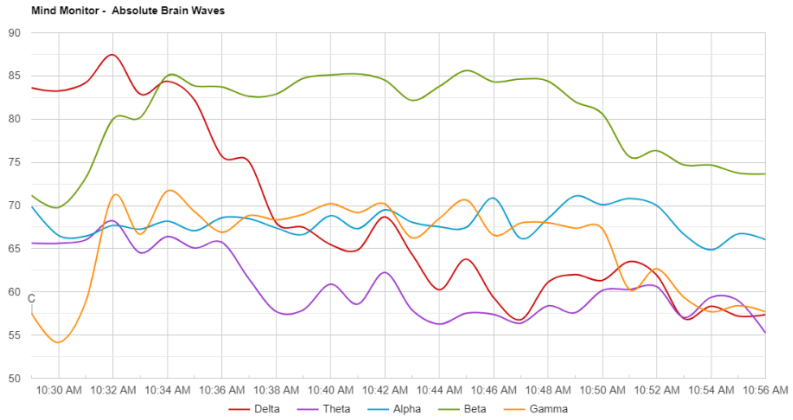


Figure 15: STROOP Test EEG Graph for the Least Fit Participant (source: self-created)

On the graphs, we examined the alpha (blue) and theta (purple) waves, comparing them within the same participant across tests, and between the fittest and least fit participants.

DISCUSSION

1. Pilot Study: Discussion

When looking at the player's initial K/D ratio data, it was relatively low compared to some professionals but average for players in similar T3-level leagues (Richman, 2022). The win rate (WR) was very weak, well below the 50-55% average. The game algorithm aims to achieve a 50% win rate to maintain the most balanced matches (Minar, 2016).

During the lifestyle change period examined in the study, in-game statistics improved. The K/D ratio increased by 0.2, which is roughly average compared to international professional players

but significantly better than the general average (Richman, 2022). The win rate increased by 14%, reaching 60%, which is well above the average (Minar, 2016).

Overall, the player showed positive changes in all areas. The K/D ratio and win percentage increased, and the number of matches played before burnout rose from 6 to 8.

Both hypotheses we formulated for this study were confirmed. The win rate increased by 14%, from 48% to 60%, and the K/D ratio improved by 18%, from 1.1 to 1.3.

This is particularly interesting because we assumed that we could influence only individual performance (K/D ratio) when formulating the hypotheses. However, the significant increase in the win rate suggests that the player's performance plays a more critical role in the outcome of ranked team matches than we initially thought.

2. Long-term Research – Sports Education: Discussion

At the beginning of the case study, the player admitted that they were not regularly physically active and had a negative attitude toward sports. Their negativity primarily stemmed from the belief that exercise was a waste of time, as they said, "the time spent working out could be spent playing games." While it is true that time spent in-game is highly correlated with e-sports performance (Sanz-Matesanz et al., 2023), it is also true that physical activity benefits mental functions (Taylor, 2022). The player eventually began to realize that exercise wasn’t necessarily a bad thing, and after working out, they felt like their "mind was clearer." This reaction was similar to that of the participant in the pilot study.

By the end of our case study, the player had adopted a more athletic mindset and began motivating those around them to live a healthy and active lifestyle. A good example of this is their time in the Spanish league with Team Heretics, where the team earned the nickname "gymbros" in the Spanish community after the player's arrival (Loemifar, 2023a), as they frequently discussed and posted about their workouts on social media during a period when the Spanish league was breaking viewership records (Nicholson, 2023).

There were two major setbacks in the player's career, both of which they managed to overcome with the help of sports. The first occurred while playing in the French league for Team BDS. At the end of their year with the team, the organization purchased a spot in the LEC (League of Legends European Championship), meaning the player could have advanced to the top-tier

league without a transfer. However, this did not happen, and by the season’s end, the player had to leave the team.

A similar situation unfolded the following year with their team, Team Heretics, in the Spanish championship. Again, their team bought a spot in the LEC franchise league. The key difference compared to Team BDS was that Team Heretics had won both the Spanish league and the Tier 2 European Masters, where the player was named the finals' MVP (Stoica, 2022). Once again, the player could have become a Tier 1 player without a transfer, but just like in the French league, they did not receive a Tier 1 contract.

These moments served as a real test of whether the player could utilize the values they had gained from sports and whether they had developed the perseverance and fighting spirit characteristic of true professional athletes.

Our hypothesis was confirmed in this case, as the professional e-sports player had become an advocate for an active lifestyle and could no longer imagine their days without physical activity, which had become a form of "therapy."

3. Medium-term Research – Sports Science: Discussion

Regarding the BORG Scale, we aimed to assign tasks that were neither too little nor overly burdensome, which is reflected in the average scores around 5. The most significant finding in this study was that participants in the control group perceived the task difficulty as increasing by one full BORG scale point over the 12 weeks, while the physical activity group experienced a decrease of 0.2 points in perceived task difficulty.

This finding aligns with the research by Leis et al. (2022), which suggests that physical activity can effectively reduce the perception of task difficulty, supporting the idea that physical activity is a viable coping mechanism for managing stress. The participants in the control group, who were denied this coping mechanism, showed an increase in perceived task difficulty.

Our first hypothesis, that the physical activity group would achieve higher ranks than the control group under the same conditions—initially appears invalid, as the control group ended the study with an average rank of Gold 4, while the physical activity group's average rank was Silver 2, which is two ranks lower. However, when considering the dropout rates and the distribution of participants with prior gaming experience, we see that 50% of the control group

had prior gaming experience, compared to only 33% in the PA group. This disparity, combined with the uneven group sizes due to dropout, complicates the analysis. In this case, our hypothesis about ranking outcomes could not be confirmed.

However, when we exclude participants with prior gaming experience from both groups, the control group's average rank changes to Silver 4, and the physical activity group's average rank changes to Silver 2. This result, showing that the PA group ranked higher on average, confirms our hypothesis regarding ranking outcomes.

Our second hypothesis, that the control group would perceive the task as more challenging over time, was clearly confirmed, as the control group's perceived task difficulty increased by one full point on the BORG Scale, while the physical activity group's perceived difficulty decreased by 0.2 points.

Among the lessons learned from this research were challenges related to participant issues, the differences in dropout rates between the control and PA groups, high equipment costs, difficulties in ensuring equal conditions, and administrative challenges.

4. Short-term Research – Sports Science: Discussion

The e-sports-specific measurements yielded several interesting results. The first and most important is that physical activity has a clear impact on mechanical skills, and in most cases, this impact is positive. It is also noteworthy that among the 12 participants, none experienced a situation where the physical activity intervention did not at least prevent a decline in one e-sports performance-related skill. In at least one aspect, the HIIT intervention applied after several hours of gameplay resulted in positive changes.

If we accept the fact that performance tends to decline over time as the e-sports player becomes fatigued, it would be logical to expect the worst results to occur in the final, fourth measurement, when the experiment had already lasted about 3 hours. However, in many cases, the fourth measurement yielded the best results, often better than the previous measurements (reaction time, keyboard skills, visual memory, and mouse skills tests in 75% of cases, and accuracy tests in 66% of cases). In only a few instances did performance decline, and even then, the decrease was minimal.

The outstanding value of the second result is also worth explaining, especially in light of why the first result isn't the best if we follow the logic of continuous fatigue. Since all participants performed the tasks on the same unfamiliar equipment, the higher scores on the second result can be explained by the fact that the participants had become accustomed to their environment, their equipment, and had "warmed up" to the task types—using terminology borrowed from traditional sports. This acclimatization helped improve their performance despite the expectation of growing fatigue.

The third measurement, which took place after 2 to 2.5 hours of testing, generally showed a decline in performance compared to the first or second measurement.

The fourth measurement results, when examined on average, sometimes exceeded those of the second measurement, particularly in reaction time, visual memory, and mouse skills. This suggests that for some players, physical activity can create an even better state than the "warmed-up" state observed in the second measurement.

Regarding the EEG graphs, it is visually apparent that despite spending a similar amount of time on the STROOP test (30 minutes) and the selected e-sports game (25-45 minutes), the EEG graphs (Figures 12-13 and 14-15) look different. During the STROOP test, the waves are much smoother, with fewer amplitude changes, whereas during the game, the alpha and theta waves, which indicate fatigue, become much more erratic.

When comparing the graphs between the fittest and least fit participants, we see that the fitter participant’s fourth EEG graph, recorded after the physical activity intervention, closely resembles the "automatic" STROOP test graph.

Comparing the third and fourth EEG graphs of the fittest participant (Figure 13) to the least fit participant's EEG graph (Figure 15), it is clear that the fitter participant's fourth graph is much closer to the STROOP test graph than their first EEG graph.

Regarding our hypotheses 1-5 (see below), we observed noticeable changes in the generated EEG graphs related to the effects of physical activity. However, we were unable to observe the increase in the energy output of alpha and theta waves as mental fatigue progressed, as described by Trejo et al. (2015) and Chai et al. (2016). Instead, we detected irregular alpha wave rhythms as described by Barnes and Brieger (1946), meaning that **our first hypothesis** could not be confirmed.

For the second hypothesis, we compared two sets of data against the cardiovascular system's VO2 data, as the mental fatigue simulation test (STROOP) generated two data sets. We found weak correlations in both cases, with one being negative (-.218) and the other positive (.172).

In the third hypothesis, similar to the second, we compared two sets of data against the time spent playing the game, as previously described. Again, we reached the same conclusion: one correlation was negative (-.315) and the other was positive (.206).

For the fourth hypothesis, we found that in fitter individuals, the amplitude of alpha and theta waves decreased after the physical activity intervention, similar to the STROOP test. However, in the least fit individual, there was no visible change.

Our fifth hypothesis requires further research to be fully answered. The current analysis suggests that physical activity does have an effect, as the EEG waves of fitter participants appeared smoother during the fourth test, which measured mental strain. However, there was no significant difference for the least fit individual.

We were able to fully confirm our **sixth hypothesis**, as the overall results showed improvements in all five areas (Reaction Time, Visual Memory, WPM, Mouse Usage, and Mouse Accuracy) during the fourth test, with some scores even surpassing those of the third test.

Finally, regarding our **seventh and last hypothesis**, we found that 11 out of 12 participants responded positively to the physical activity intervention, reporting feeling more refreshed and experiencing improved well-being afterward.

CONCLUSION

We can observe that the anticipated and increasingly applied integration of physical activity in e-sports on an international level can indeed impact performance. However, what has yet to be supported by data is that this effect manifests not only in subjective experiences (which are also extremely important) but also in objective indicators that influence and form the foundation of e-sports performance.

When looking at the results of this short-term research, breaking up a 2-3 hour gaming session with physical activity not only halts the decline in performance caused by mental fatigue but

also shifts it in a positive direction. There was no participant in our study who did not show improvement in at least one of the examined factors.

Another important finding from this PhD dissertation's research is that sports indeed serve as an excellent stress management mechanism. Through this, members of the subculture involved in e-sports and video games can receive positive feedback, enabling a long-term approach to fostering a more active and healthy lifestyle through sports.

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Andre, T. L., Walsh, S. M., Valladão, S., & Cox, D. (2020). Physiological and Perceptual Response to a Live Collegiate E-sports Tournament. *International Journal of Exercise Science*, *13*(6), 1418-1429. https://pubmed.ncbi.nlm.nih.gov/33042382/

Barnes T., C. & H. Brieger (1946) Electroencephalographic Studies of Mental Fatigue, *The Journal of Psychology*, *22*(2), 181-192, https://doi.org/10.1080/00223980.1946.9917305

Behnke, M., Gross, J. J., & Kaczmarek, L. D. (2022). The role of emotions in e-sports performance. *Emotion*, *22*(5), 1059–1070. https://doi.org/10.1037/emo0000903

Cantrell, W. A., Cantrell, C., Cruickshank, J., Schwartz, D., Aaron, D., Belle, J., Schaffer, J., & King, D. (2023). *E-sports*. In B. J. Krabak & A. Brooks (Eds.), The Youth Athlete (Chapter 71, pp. 761-767). Academic Press. ISBN 9780323999922. https://doi.org/10.1016/B978-0-323-99992-2.00030-X

Chai, R., Tran, Y., Naik, G. R., Nguyen, T. N., Ling, S. H., Craig, A., & Nguyen, H. T. (2016). *Classification of EEG based-mental fatigue using principal component analysis and Bayesian neural network*. In 2016 38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), 4654-4657. https://doi.org/10.1109/EMBC.2016.7591765

Chan, G., Huo, Y., Kelly, S., Leung, J., Tisdale, C., & Gullo, M. (2022). The impact of e-sports and online video gaming on lifestyle behaviours in youth: A systematic review. *Computers in Human Behavior*, *126*. https://doi.org/10.1016/j.chb.2021.106974

Czakó, A., Király, O., Koncz, P., Yu, S. M., Mangat, H. S., Glynn, J. A., Romero, P., Griffiths, M. D., Rumpf, H.-J., & Demetrovics, Z. (2023). Safer e-sports for players, spectators, and bettors: Issues, challenges, and policy recommendations. *Journal of Behavioral Addictions*, *12*(1), 1–8. https://doi.org/10.1556/2006.2023.00012

De Las Heras, B., Li, O., Rodrigues, L., Nepveu, J., & Roig, M. (2020). Exercise improves video game performance: A win-win situation. *Medicine & Science in Sports & Exercise*, 52(7), 1595–1602. https://doi.org/10.1249/MSS.0000000000002277

DiFrancisco-Donoghue, J., Jenny, S. E., Douris, P. C., Ahmad, S., Yuen, K., Hassan, T., Gan, H., Abraham, K., & Sousa, A. (2021). Breaking up prolonged sitting with a 6 min walk improves executive function in women and men e-sports players: a randomised trial. *BMJ Open Sport & Exercise Medicine*, *7*. https://doi.org/10.1136/bmjsem-2021-001118

Ding, Y., Hu, X., Li, J., Ye, J., Wang, F., & Zhang, D. (2018). What Makes a Champion: The Behavioral and Neural Correlates of Expertise in Multiplayer Online Battle Arena Games. *International Journal of Human–Computer Interaction*, *34*(8), 682-694. https://doi.org/10.1080/10447318.2018.1461761

Dykstra, R., Koutakis, P., & Hanson, N. (2021). Relationship between physical fitness variables and reaction time in e-sports gamers. *International Journal of e-sports Research*, 1(1), 8540. https://doi.org/10.4018/IJER.288540

Hallmann, K., & Giel, T. (2017). e-sports – Competitive sport or recreational activity. *Sport Management Review*, *21*, 14-20. https://doi.org/10.1016/j.smr.2017.07.011

Haupt, S., Wolf, A., Heidenreich, H., & Schmidt, W. (2021). Energy expenditure during e-sports – a case report. *Deutsche Zeitschrift für Sportmedizin*, *72*, 36-40. https://doi.org/10.5960/dzsm.2020.463

Himmelstein, D., Liu, Y., & Shapiro, J. L. (2017). An exploration of mental skills among competitive league of legend players. *International Journal of Gaming and Computer-Mediated Simulations*, *9*(2), 1–21. https://doi.org/10.4018/IJGCMS.2017040101

Jenny, E. S., Manning, D. R., Keiper, C. M., & Olrich, W. T. (2016). Virtual(ly) athletes: Where e-sports fit within the definition of sport. *Quest*, *69*(1), 1-18. https://doi.org/10.1080/00336297.2016.1144517

Jonasson, K., & Thiborg, J. (2010). Electronic sport and its impact on future sport. *Sport in Society*, *13*(2), 287-299. https://doi.org/10.1080/17430430903522996

Kane, D., & Spradley, B. D. (2017). Recognizing E-sports as a Sport. *U.S. Sports Academy*. letöltve: https://www.researchgate.net/profile/Daniel-Kane-6/publication/317929457_Recognizing_E-sports_as_a_Sport/links/597f4db5a6fdcc1a9acd7fe1/Recognizing-E-sports-as-a-Sport.pdf

Kari, T., & Karhulahti, V. (2016). Do e-athletes move? A study on training and physical exercise in elite e-sports. *International Journal of Gaming and Computer-Mediated Simulations*, *8*, 53-66. https://doi.org/10.4018/IJGCMS.2016100104

Kari, T., Siutila, M., & Karhulahti, V. (2019). An Extended Study on Training and Physical Exercise in E-sports. In B. Dubbels (Ed.), *Exploring the Cognitive, Social, Cultural, and Psychological Aspects of Gaming and Simulations* (pp. 270-292). IGI Global. https://doi.org/10.4018/978-1-5225-7461-3.ch010

Kocić, A., Božović, B., Vićentijević, A., Kocić, J., & Milošević, M. (2022). The Influence of Physical Activity on the Health and Playing Quality of the E-Sports Players. In *Sinteza 2022 - International Scientific Conference on Information Technology and Data Related Research*, *Stranice*, 287-291. https://doi.org/10.15308/Sinteza-2022-287-291

Lazarus, R. S. (2000). How Emotions Influence Performance in Competitive Sports. *The Sport Psychologist*, *14*(3), 229-252. https://doi.org/10.1123/tsp.14.3.229

Lee, D., & Schoenstedt, L. J. (2011). Comparison of e-sports and Traditional Sports Consumption Motives. *ICHPER-SD Journal of Research*, *6*(2), 39-44. letöltve: https://eric.ed.gov/?id=EJ954495

Leis, O., & Lautenbach, F. (2020). Psychological and physiological stress in non-competitive and competitive e-sports settings: A systematic review. *Psychology of Sport and Exercise*, *51*, 101738. https://doi.org/10.1016/j.psychsport.2020.101738

Leis, O., Franziska, L., Birch, P.D., & Elbe, A.-M. (2022). Stressors, perceived stress responses, and coping strategies in professional e-sports players: A qualitative

study. *International Journal of E-sports Research*, *1*(1), 76. letöltve: https://www.ije-sports.org/article/76/html

Leis, O., Raue, C., Dreiskämper, D., & Lautenbach, F. (2021). To be or not to be (e)sports? That is not the question! Why and how sport and exercise psychology could research e-sports. *German Journal of Exercise and Sport Research*, *51*(2), 241–247. https://doi.org/10.1007/s12662-021-00715-9

Loemifar. (2023, November 28)a. LOL: Ott a bejelentés, megtalálta új csapatát Subicz "Bluerzor" Dániel. *Esport1*. Letöltve: https://e-sport1.hu/news/2023/11/28/lol-league-of-legends-bluerzor-zero-tenacity-hivatalos-bejelentes-ultraliga-2024-loemifar

Lubans, D., Richards, J., Hillman, C., Faulkner, G., Beauchamp, M., Nilsson, M., Kelly, P., Smith, J., Raine, L., & Biddle, S. (2016). Physical activity for cognitive and mental health in youth: A systematic review of mechanisms. *Pediatrics*, *138*(3), 1642. https://doi.org/10.1542/peds.2016-1642

Ludyga, S., Gerber, M., Pühse, U., Looser, V.N., & Kamijo, K. (2020). Systematic review and meta-analysis investigating moderators of long-term effects of exercise on cognition in healthy individuals. *Nature Human Behaviour*, *4*, 603–612. https://doi.org/10.1038/s41562-020-0851-8

Lynch, J. (2017). As NFL ratings drop, a new internet study says young men like watching e-sports more than traditional sports. *Business Insider*. https://www.businessinsider.com/nfl-ratings-drop-study-young-men-watch-e-sports-morethan-traditional-sports-2017-9

Magistretti, P. J., & Allaman, I. (2015). A cellular perspective on brain energy metabolism and functional imaging. *Neuron*, 86(4), 883-901. https://doi.org/10.1016/j.neuron.2015.03.035

McNulty, C., Jenny, S. E., Leis, O., Poulus, D., Sondergeld, P., & Nicholson, M. (2023). Physical Exercise and Performance in E-sports Players: An Initial Systematic Review. *Journal of Electronic Gaming and E-sports*, *1*(1), jege.2022-0014. https://doi.org/10.1123/jege.2022-0014

Minar, N. (2016, September 12). League of Legends win rates by tier. *Somebits.* Letöltve: https://www.somebits.com/~nelson/lol-stats-notebooks-2016/League+of+Legends+win+rates+by+tier.html

Nicholson, J., (2023). LVP records major viewership growth for 2022. *E-sports Insider*. https://e-sportsinsider.com/2023/01/lvp-2022-viewership-growth

Park, J. H., Moon, J. H., Kim, H. J., Kong, M. H., & Oh, Y. H. (2020). Sedentary lifestyle: Overview of updated evidence of potential health risks. *Korean Journal of Family Medicine*, *41*(6), 365-373. https://doi.org/10.4082/kjfm.20.0165

Richman, O. (2022, February 2). Does K/D matter in Rainbow Six Siege? *Siege.gg*. Letöltve: https://siege.gg/news/2803-does-kd-matter-in-rainbow-six-siege

Sanz-Matesanz, M., Gea-García, G. M., & Martínez-Aranda, L. M. (2023). Physical and psychological factors related to player's health and performance in e-sports: A scoping review. *Computers in Human Behavior*, *143*, 107698. https://doi.org/10.1016/j.chb.2023.107698

Schuch, F.B., Vancampfort, D., Richards, J., Rosenbaum, S., Ward, P.B., & Stubbs, B. (2016). Exercise as a treatment for depression: A meta-analysis adjusting for publication bias. *Journal of Psychiatric Research*, *77*, 42–51. https://doi.org/10.1016/j.jpsychires.2016.02.023

Sharpe, B. T., Besombes, N., Welsh, M. R., & Birch, P. D. (2023). Indexing E-sport Performance, *Journal of Electronic Gaming and E-sports*, *1*(1). https://doi.org/10.1123/jege.2022-0017

Sousa, A., Ahmad, S. L., Hassan, T., Yuen, K., Douris, P., Zwibel, H., & DiFrancisco-Donoghue, J. (2020). Physiological and cognitive functions following a discrete session of competitive e-sports gaming. *Frontiers in Psychology*, *11*. https://doi.org/10.3389/fpsyg.2020.01030

Stoica, M. (2022, November 15). Sources: Marlon set to join Team Heretics and Bluerzor to extend his contract. *Blix.gg*. Letöltve:https://blix.gg/news/marlon-bluerzor-hrtcs

Szabella, O. (2018). Korunk virágzó biznisze? Az e-sport iparág bemutatása. *Információs Társadalom*, 66-92. http://dx.doi.org/10.22503/inftars.XVIII.2018.1.5

Taylor, J. (2022, May 16). *Effects of physical activity on mental health in vulnerable populations*. ACSM Blog. https://www.acsm.org/blog-detail/acsm-blog/2022/05/16/effects-physical-activity-mental-health-vulnerable-populations

Toth, A. J., Kowal, M., & Campbell, M. J. (2019). The Color-Word Stroop Task Does Not Differentiate Cognitive Inhibition Ability Among E-sports Gamers of Varying Expertise. *Frontiers in Psychology*, *10*. https://doi.org/10.3389/fpsyg.2019.02852

Toth, A. J., Ramsbottom, N., Kowal, M., & Campbell, M.J. (2020). Converging evidence supporting the cognitive link between exercise and e-sport performance: A dual systematic review. *Brain Sciences*, *10*(11), 859. https://doi.org/10.3390/brainsci10110859

Trejo, L. J., Kubitz, K., Rosipal, R., Kochavi, R. L., & Montgomery, L. D. (2015). EEG-Based Estimation and Classification of Mental Fatigue. *Psychology*, *6*(5), 55-71. https://doi.org/10.4236/psych.2015.65055

Trotter, M. G., Coulter, T. J., Davis, P. A., Poulus, D. R., & Polman, R. (2020). The Association between E-sports Participation, Health and Physical Activity Behaviour. *International Journal of Environmental Research and Public Health*, *17*(19). http://dx.doi.org/10.3390/ijerph17197329

Valladão, S. P., Middleton, J., & Andre, T. L. (2020). E-sport: Fortnite Acutely Increases Heart Rate of Young Men. *International Journal of Exercise Science*, 13(6), 1217-1227 https://pubmed.ncbi.nlm.nih.gov/33042380/

Voisin, N., Besombes, N., & Laffage-Cosnier, S. (2022). Are e-sports players inactive? A systematic review. *Physical Culture and Sport Studies and Research, 97*(1), 32-52. https://doi.org/10.2478/pcssr-2022-0022

Watanabe, K., Saijo, N., Minami, S., & Kashino, M. (2021). The effects of competitive and interactive play on physiological state in professional e-sports players. *Heliyon*, *7*(4), e06844. https://doi.org/10.1016/j.heliyon.2021.e06844

Wattanapisit, A., Wattanapisit, S., & Wongsiri, S. (2020). Public health perspectives on e-sports. *Public Health Reports*, *135*(3), 295-298. https://doi.org/10.1177/0033354920912718

Wilke, J., Giesche, F., Klier, K., Vogt, L., Herrmann, E., & Banzer, W. (2019). Acute effects of resistance exercise on cognitive function in healthy adults: A systematic review with multilevel meta-analysis. *Sports Medicine*, *49*, 905–916. https://doi.org/10.1007/s40279-019-01085-x

Yin, K., Zi, Y., Zhuang, W., Gao, Y., Tong, Y., Song, L., & Liu, Y. (2020). Linking E-sports to health risks and benefits: Current knowledge and future research needs. *Journal of Sport and Health Science*, *9*(6), 485-488. https://doi.org/10.1016/j.jshs.2020.04.006

Zhao, Y.-L., Zhang, Z., & Cheng, C.-X. (2015). The Influence of Teachers' Appearance in the Process of Teaching on the Teaching Effect. Paper presented at the *International Conference on Informatization in Education, Management and Business*

SAJÁT PUBLIKÁCIÓK A TÉMÁBAN

Szabella, O. (2018). Korunk virágzó biznisze? Az e-sport iparág bemutatása. *Információs Társadalom*, 66-92. http://dx.doi.org/10.22503/inftars.XVIII.2018.1.5

Szabella, O. (2021). A Covid-19 hatása az e-sport iparágára. In Gősi, Z., Boros, S., & Magyar, M. (Eds.), *A sport szerepe a Covid-19 pandémia árnyékában*. Akadémiai Kiadó. https://doi.org/10.1556/9789634546610

Szabella, O., Szabó, A., & Kassay, L. (2024). E-sport performance measurement with physical activity intervention. *Sprint, Sports Research International, 1*(Supplement 1), 8. https://portal.issn.org/resource/ISSN/3057-8779

Szabella, O., Szabó, A., & Kassay, L. (2024). A fizikai aktivitás longitudinális hatásai az e-sport játék rangsorolt eredményére. *Magyar Sporttudományi Szemle, 108*(2), 102-103.

Magyar Sporttudományi Társaság. XXI. Országos Sporttudományi Kongresszus: Sporttudomány az egészség és a teljesítmény szolgálatában, Székesfehérvár, Magyarország, 2024.05.29 - 2024.05.31.

Szabella, O., Kassay, L., & Szabó, A. (2024). E-sport performance measurement with physical activity intervention. In *Proceedings of the Conference at Testnevelési Egyetem* Budapest, Hungary, 2024.04.24 - 2024.04.27

Szabella, O., Kassay, L., & Szabó, A. (in press). Relationship between esports and physical activity participation: Validation of the Esports Addiction Scale (ESAS). *Baltic Journal of Health and Physical Activity*.

Szabella, O., Kassay, L., & Szabó, A. (in press). A fizikai aktivitás longitudinális hatásai az e-sport játék rangsorolt eredményére. *Magyar Sporttudományi Szemle*. 2024/6 ISSN 158-5428