applied sciences

MDPI

Article

Examining Physiological Changes during Counter-Strike: Global Offensive (CS:GO) Performance in Recreational Male Esports Players

Dorota Sadowska [1,*], Tomasz Sacewicz [2], Kinga Rębiś [1], Tomasz Kowalski [1] and Justyna Krzepota [3]

[1] Department of Physiology, Institute of Sport—National Research Institute, ul. Trylogii 2/16, 01-982 Warsaw, Poland; kinga.rebis@insp.pl (K.R.)
[2] Department of Biomechanics and Computer Science, Faculty of Physical Education and Sport in Biała Podlaska, Józef Piłsudski University of Physical Education in Warsaw, 21-500 Biała Podlaska, Poland; tomasz.sacewicz@awf.edu.pl
[3] Institute of Physical Culture Sciences, University of Szczecin, al. Piastów 40B, blok 6, 71-065 Szczecin, Poland; justyna.krzepota@usz.edu.pl
* Correspondence: sadowska.dorota@hotmail.com

Abstract: While the training of professional sports athletes and the factors determining sports success are based on well-established scientific research, esports training and markers of esports performance are not yet fully recognized or explored. Knowledge of the psychophysiological responses of the athlete's body to esports competition is the necessary foundation for rational training management. The aim of the present study was to evaluate physiological stress while playing Counter-Strike: Global Offensive (CS:GO). Selected cardiovascular, hormonal, and biochemical indices were monitored to assess differences in stress responses between winners and losers. Twenty-two male players participated in the study (age 22.0 ± 2.0 years, CS:GO training experience 7.0 ± 2.2 years, training load 24.6 ± 11.5 h per week). Each player played two games during the CS:GO competition. The CS:GO tournament induced an increase in heart rate (HR), systolic blood pressure, and blood cortisol levels (C), and a decrease in the nonlinear heart rate variability (HRV) index based on the fractal correlation properties, called alpha1, of detrended fluctuation analysis (DFA-alpha1). In contrast, no changes were observed in blood levels of testosterone (T) and lactate (BLa). It was found that changes in physiological indices in players while playing CS:GO did not differentiate between winners and losers. The changes in the physiological parameters recorded during play indicate that CS:GO tournaments induce significant physiological arousal and can be considered a stressor.

Keywords: esports; CS:GO; physiological stress; competition

Citation: Sadowska, D.; Sacewicz, T.; Rębiś, K.; Kowalski, T.; Krzepota, J. Examining Physiological Changes during Counter-Strike: Global Offensive (CS:GO) Performance in Recreational Male Esports Players. *Appl. Sci.* **2023**, *13*, 11526. https://doi.org/10.3390/app132011526

Academic Editor: Roger Narayan

Received: 9 September 2023
Revised: 12 October 2023
Accepted: 19 October 2023
Published: 20 October 2023

1. Introduction

Practiced both professionally and recreationally, esports is a thriving field, and sports science is devoting more and more attention to it [1]. Currently, the viewership of major esports tournaments is comparable to that of many traditional sports. According to Newzoo, the number of esports viewers worldwide in 2021 exceeded 465 million people. This number is projected to grow to nearly 580 million by 2024 [2].

While the training of professional sports athletes and the factors determining sports success are based on well-established scientific research, esports training and markers of esports performance are not yet in the full scope of sports science. However, they are crucial for optimizing coaching, prescribing adequate training and predicting performance. Moreover, knowledge of the psychophysiological responses of the athlete's body to esports competition is the basis of rational training management. There are reports in the literature on the effects of playing video games and esports on behavior and brain function. Research findings indicate that action video games enhance a wide range of perceptual–cognitive

skills [3,4]. The associations of electronic games with, among other things, aggression [5,6], depression [7,8] or addiction [9] have also been analyzed. However, only a few studies deal with e-sports. Kumari et al. [10] observed no significant relationship between e-sports and anxiety, whereas a positive relationship was found between e-sports and aggression, and a negative relationship was found between e-sports and psychological well-being. Moreover, to our knowledge, and according to the related scientific literature, significant gaps remain in the physiological and performance-related aspects of participation in esports.

Esports games are complex and can be divided into specific genres, such as multiplayer online battlefield arena (MOBA), first-person shooter (FPS) and real-time strategy (RTS) and sport simulations [11]. In every genre there are different digital games, with different competition rules and different mechanics that have to be mastered by the players. Furthermore, different games at different levels of competition place different demands on the player. Therefore, in order to understand and describe the physiological responses in players during a game as accurately as possible, the focus should be on one particular game. In our research, we have decided to focus on Counter-Strike: Global Offensive (CS:GO), one of the most popular e-sports games. CS:GO is a tactical FPS game based on a first-person shooter perspective. Players use their mouse to control the character's view, typically to aim toward and shoot enemies [12]. The CS:GO game demands high visuomotor coordination, fast reaction time, optimal perceptual skills, good planning behavior, high flexibility, and appropriate inhibition [13]. Esports competitions are accompanied by strong emotions that cause physiological responses. These include neuroendocrine responses (the release of stress hormones such as testosterone, cortisol, and ACTH), increased blood pressure, change in heart rate (HR) and heart rate variability (HRV), increased muscle tension and biochemical changes in the body [14–16]. A study by Sousa et al. [17] found that, compared to the game genre MOBAs, FPS games induce larger change in low-to-peak heart rate and systolic blood pressure [17].

Few studies exist in the literature on the changes in hormone concentrations during the playing of esports games. However, as the investigated populations and game genres differ, the results of these studies remain inconclusive. Gray et al. [18] observed no changes in testosterone, cortisol, dehydroepiandrosterone, and androstenedione levels in young gamers playing League of Legends. Different results were obtained by Schmidt et al. [19], who reported a significant increase in cortisol levels immediately following competition. The authors also noted the different hormonal response patterns of the tournament participants and stratified them into subgroups according to the observed direction of change in cortisol levels. One of the few studies conducted in the field of esports physiology concerns the relationships between a player's skill level and the hormonal and cardiovascular responses recorded during a match [20]. The authors did not observe differences in cortisol levels between athletes with high and low skills. For testosterone, on the other hand, a varied response pattern was observed, depending on skill level. In the group of low-skilled players, a significant increase in testosterone levels was found during play, while no change was observed in the group of high-skilled players. There were no differences in the heart rate characteristics between the groups with different skill levels.

The analysis of HRV dynamics to assess the arousal effects during esports games remains an understudied area. Stress influences the autonomous nervous system (ANS), which controls a person's ability to react to external stimuli [21]. Therefore, acute stress may be evaluated with non-invasive measurements, which are considered reliable estimators of the ANS status. This is the case with HRV, which is considered a reliable means to indirectly observe ANS [22]. Recently, researchers using different measures of HRV were able to observe a shift towards a sympathetic activation combined with a parasympathetic withdrawal after different tasks to provoke mental stress (i.e., computer work tasks, academic examinations, physical/mental tasks, public speech tasks, game tasks, arithmetic tasks, the Stroop color word task) [23]. Gündoğdu et al. [24] showed that a linear and nonlinear dynamics analysis of HRV has been a non-invasive marker in the separation of rest and game states in playing a puzzle video game.

Improving the performance of esports players requires training methods that take into account the specific competence profile of the respective esports game [11]. The evaluation of physiological arousal during CS:GO tournaments measured using selected cardiovascular, hormonal, and biochemical indicators, and the differences in stress responses in winners and losers, which is the subject of the present study, will be the first step toward developing effective training techniques aimed at CS:GO players.

2. Materials and Methods

2.1. Participants

The study was conducted in accordance with the Declaration of Helsinki. The study protocol was approved by the Institute of Sport—National Research Institute Ethics Committee (approval No. KEBN-23-85-DS). Participants were informed about the applied procedures in oral and written forms. All participants gave their written informed consent before participating voluntarily in the study. Participants were free to withdraw from the study at any time without further consequences. The inclusion criteria were as follows: over 18 years old, at least 5 years of esports training, at least 3 years of CS:GO training and at least 10 h of weekly esports training during the previous 3 months. The exclusion criteria were as follows: no chronic or acute medical condition and a lack of any ongoing medication. The participant group consisted of 20 male players aged 22.0 ± 2.0, recruited with convenience sampling. All the participants were physical education students majoring in esports. The training experience of the players studied was 9.0 ± 2.2 years, whereas with the CS:GO game, it was 7.0 ± 2.2 years. The players declared they had spent 24.6 ± 11.5 h per week on esports training and gaming, and 6.0 ± 3.5 h per week on sports activities and exercise. The training data were self-reported. The day before the tournament, in the morning, basic somatic characteristics and body compositions were measured using the bioelectrical impedance method (TANITA's BC 418 analyzer) (Table 1).

Table 1. Basic somatic characteristics and body compositions of esports players.

	Mean ± SD
Body height [cm]	184.5 ± 7.6
Body mass [kg]	81.6 ± 16.8
BMI [kg/m^2]	23.9 ± 4.8
Fat mass [kg]	14.0 ± 8.2
Fat [%]	16.2 ± 5.9
Fat-free mass [kg]	67.1 ± 9.9

2.2. Testing Procedure

In this research, a CS:GO tournament was organized as an individual competition. The CS:GO tournament conducted in the study consisted of two stages. During each stage, the players played one match/game each. In the first stage of the competition, opponents were randomly matched in pairs. In the second stage, matches were played between the winners and losers from the first stage, also using random matching. All matches were held on the same day in the afternoon and evening (3 p.m. to 9 p.m.). Matches were played to 16 frags (kills). The duration of the game ranged from 4 to 7 min (5.2 ± 1.1 min).

Blood samples for cortisol (C), testosterone (T), and blood lactate (BLa) were obtained from the players 10 min before the match. Subsequently, the players prepared their stance for the game and then remained seated for about 5 min. Then, blood pressure measurements were taken and the HR measurements started. The HR measurements continued during the match. Immediately after the match, blood pressure was measured again, and 5 min after the match, blood samples were obtained again to evaluate C, T, and BLa levels. The study design timeline is presented in Figure 1.

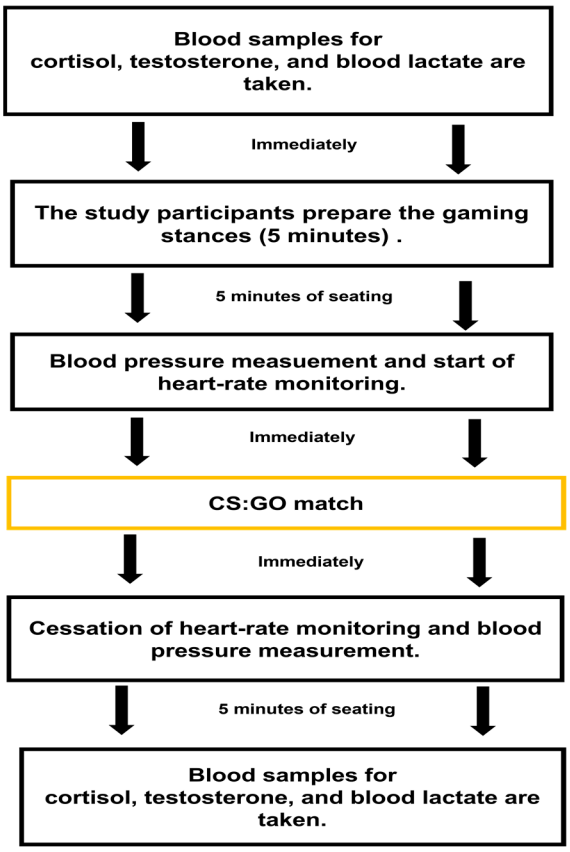

Figure 1. Schematic presentation of the study design timeline.

2.3. Measured Blood Markers

All the blood indices (C, T, BLa) were measured in capillary blood samples collected from the fingertip before and after each esports match. A Super GL2 analyzer (Dr. Müller Gerätebau GmbH, Freital, Germany) was used to measure BLa. ELISA tests (DRG International Inc., Springfield, NJ, USA) were used to evaluate cortisol and testosterone levels. Assays were performed according to the procedure for performing ELISA.

2.4. Cardiac Activity Indices

Heart rate (resting HR, mean HR, maximum HR) and HRV were monitored during esports games. The lowest heart rate recorded in players during a 5 min rest before the match was considered the resting HR.

HRV is the phenomenon of the variation in the time intervals between sequential heartbeats. There are many techniques for the analysis of HRV [25]. Recently, the nonlinear dynamics of HRV have received increasing attention. Detrended fluctuation analysis of HRV and its short-term scaling exponent alpha1 (DFA-alpha1) were presented as a useful measure to detect stress conditions [21] and investigate the complex regulations during exercise, inter alia, to monitor intensity in endurance sports or to detect intensity thresholds [26]. In our study, HR and DFA-alpha1 were measured with a Polar H10 chest strap (Polar Electro Oy, Kempele, Finland) and calculated with the Heart Rate Variability Logger app set with a 2 min computation window and workout mode for R-R intervals with a correction of 5% (A.S.M.A. B.V., Marco Altini, Version 5.1.0, downloaded from Mac App Store on 3 February 2023).

2.5. Blood Pressure Measurements

Digital measurements of peripheral blood pressure were performed using a validated, automatic OMRON M2 blood pressure monitor (OMRON Healthcare, Kyoto, Japan). Blood

pressure was measured in a seated position after a 5 min rest (before the match) and immediately after the match was over.

2.6. Statistical Analysis

All statistical analyses were carried out using Statistica 13.1 (StatSoft, Inc., Tulsa, OK, USA). Statistical significance level was set at $p \leq 0.05$. The normality of the distribution was verified using the Shapiro–Wilk test. The distributions of all variables did not differ from the normal distribution. Comparative analysis of the post-match cardiovascular response between winners and losers was carried out using independent Samples *t*-test. To assess the significance of differences in blood pressure, blood lactate and hormone levels recorded before and after the match in winners and losers, a Student's *t*-test for dependent samples was used.

3. Results

A comparative analysis of the post-match cardiovascular response between winners and losers showed that resting HR, mean HR, maximum HR and DFA-alpha 1 were not significantly different (Table 2).

Table 2. Cardiac activity recorded in winners and losers during esports games.

Cardiac Activity Indicators	Winners Mean ± SD	Losers Mean ± SD	*p*-Value
Resting HR [beat/min]	80 ± 12	76 ± 12	ns
Maximum HR [beat/min]	131 ± 16	125 ± 23	ns
Mean HR [beat/min]	106 ± 18	104 ± 18	ns
DFA-alpha1	1.13 ± 0.22	1.15 ± 0.26	ns

HR—heart rate; DFA-alpha1—alpha1 of Detrended Fluctuation Analysis; ns—lack of statistical significance.

Table 3 shows a comparison of the blood pressure values of the endocrine indices and BLa recorded before and after the games in winners and losers. Both winners and losers showed a significant increase in systolic pressure, while there was no significant change in diastolic pressure. In both groups, the tournament did not induce significant changes in BLa. In contrast, significant changes were found for hormonal responses. The competition induced a statistically significant increase in C levels in all the players, while there were no significant changes in T levels in either the winners or losers.

Table 3. Mean values, standard deviations and significance of differences for blood pressure, blood lactate and levels of the analyzed hormones recorded before and after e-sport games in winners and losers.

	Winners			Losers		
	Pre-Game Mean ± SD	Post-Game Mean ± SD	*p*-Value	Pre-Game Mean ± SD	Post-Game Mean ± SD	*p*-Value
Systolic BP [mm Hg]	136.6 ± 12.4	144.3 ± 15.5	0.021	133.9 ± 13.2	142.0 ± 10.5	0.005
Diastolic BP [mm Hg]	79.6 ± 10.2	82.0 ± 9.7	ns	75.1 ± 10.3	76.7 ± 9.6	ns
BLa [mmol/L]	0.96 ± 0.38	1.09 ± 0.30	ns	1.06 ± 0.27	1.10 ± 0.28	ns
Testosterone [nmol/L]	11.1 ± 4.3	10.8 ± 3.7	ns	10.0 ± 3.1	10.4 ± 3.3	ns
Cortisol [nmol/L]	320.7 ± 85.9	462.0 ± 163.6	<0.001	302.5 ± 131.8	433.3 ± 170.8	<0.001

BP—blood pressure; BLa—blood lactate; ns—lack of statistical significance.

4. Discussion

It is well understood that the competition and stress inherent in both traditional sports and esports induce various alterations in the human body [27–29]. The stress response that occurs during esports tournaments induces physiological and hormonal changes, as has been repeatedly observed in studies [27,30]. Several factors influence the magnitude and scope of these changes, including the genre of video games [31], competitive or non-

competitive playing conditions [27], tournament level [30] and player experience and skills [30].

In this study, commonly used cardiac activity indices (resting HR, mean HR, maximum HR), DFA-alpha1 and blood pressure measurements were used to assess the cardiovascular response during the playing of CS:GO. Psychophysiological stress reactions involve a complex response of the nervous and hormonal system. Relevant indices, such as HR, BP, T and C changes are commonly included in theoretical models of human competition and associated stress [27]. The CS:GO tournament conducted in this study induced an increase in player HR. The mean maximum HR recorded in our study was 128 $\pm$ 20 bpm and did not differ significantly between the groups of winners and losers. This observation confirms previous reports that the HR of esports participants is increased during games [17,32,33]. Melillo et al. [21] demonstrated that DFA-alpha1 and other measures based on nonlinear features of HRV are highly useful for stress detection. Like most features of HRV, DFA-alpha1 is significantly reduced in a stressful situation. Mellilo et al. [21] examined 42 students under stressful conditions (during an ongoing university examination) and after a holiday period (far away from stress induced by study routines). In non-stressed conditions, the mean DFA-alpha1 values were 1.413 $\pm$ 0.16, while they dropped to 1.054 $\pm$ 0.45 in stressed conditions. The results of the statistical analyses showed that the mean values of DFA-alpha1 < 1.2479 can be considered a reliable index of stress. In our study, the mean DFA-alpha1 values during the competition were 1.13 $\pm$ 0.22 in the group of winners and 1.15 $\pm$ 0.26 in the group of losers, indicating that the CS:GO games were a stressful situation for the participants.

Immediately after the games, the players' systolic blood pressures were significantly higher than those recorded before the competition, while there was no change in diastolic blood pressures. Our observations are consistent with the findings of Ballard et al. [34]. The authors monitored, in three weekly sessions, the heart rate and blood pressure changes occurring in 41 players playing a video game. The results showed that regardless of the type of game (basketball, fighting or horror), there was an increase in HR and systolic blood pressure during the game, but no change was found in diastolic blood pressure. In contrast, a significant increase in diastolic blood pressure during violent video games was reported by Siervo et al. [35]. Furthermore, Chaput et al. [36], in a study conducted on a group of adolescents, documented both an increase in HR and systolic and diastolic blood pressures while playing a video game in comparison to in resting conditions.

While playing CS:GO, players are permanently under threat of "being shot" by enemies. Even though it is only a virtual threat, this seems to be very similar to the real anticipation of a harmful or even fatal injury [37]. The CS:GO tournament triggered an increase in blood cortisol levels, confirming that this first-person shooter game could be classified as a stressor. An increase in cortisol levels during play has also been noted by other authors, including Ayhan [38] and Schmidt [19]. Similar to Schmidt et al. [19], we found no differences in cortisol levels between the winning and losing groups. However, the authors observed different patterns of changes in cortisol levels. While the best results were achieved by athletes with low or moderate increases in cortisol levels, the poorest performance was observed in the group with decreases in this hormone. Furthermore, in studies by Kindermann et al. [37] and Gray [18], no game-induced changes were observed in cortisol levels, but the examinations were conducted in non-competitive settings. Interesting observations on changes in salivary cortisol levels, depending on the type of game, were documented by Aliyari et al. [31]. The research findings revealed that the concentration of salivary cortisol and α-amylase increased significantly after playing a fear-inducing game or exciting game and decreased significantly after playing a logic-based game (Puzzle).

In our study, we did not observe significant changes induced by the CS:GO tournament in players' blood testosterone levels. The level of the hormone also did not differ between the groups of winners and losers. Furthermore, Gray et al. [18] found no significant differences in testosterone levels during a League of Legends tournament. Interesting

conclusions were drawn in a study by Mazur et al. [39]. The authors observed anticipatory increases in testosterone levels before the start of a video game match, likely triggered by the anticipation of the match. In contrast, immediately before and during the match, the authors no longer found changes in the levels of this hormone. Perhaps the lack of significant differences in blood testosterone levels observed in our study was due to the fact that they were measured immediately before the match.

While playing CS:GO, players engage the muscles of both upper limbs while using a mouse and a keyboard simultaneously. The movements made by the players must be precise and very fast. The manual dexterity that is needed to perform the actions required to compete has a direct impact on the athlete's performance [40]. Research indicates that, whereas novice players average approximately 50 action moves per minute, higher-level athletes make 10 moves per second, or 500–600 action moves per minute [40,41]. Interestingly, our study did not show an increased accumulation of blood lactate after playing CS:GO. We suppose that the lack of recorded changes may be due to both too few muscle groups being activated during the game and the duration of the tournament being too short (about 6 min). It is worth noting that, in real-world settings, esports competitions are likely to last as long as 3 to 6 h. Only one paper in the literature evaluated BLa levels while playing video games. The study was conducted in a group of boys aged 7 to 10 years playing an action video game on a Sony Playstation. The authors noted an 18.2% increase in lactate levels compared to the baseline, but this change was not statistically significant. Increased lactate accumulation, however, has been found repeatedly during active video games, which are considered a potential intervention tool to increase physical activity among children and adults [42,43].

This study has some limitations that should be addressed. The CS:GO tournament was designed specifically for this study. Consequently, playing conditions were very different from real-world tournament settings. First of all, the playing time was much shorter than in real tournaments, and the players played individually. Perhaps the stronger stress and emotion and the longer playing time during real tournaments induce a stronger psychophysiological response in the human body and greater changes in the parameters studied here. However, given the players' comfort, that has to be ensured during a real match, many of the measurements taken in our study could not have been performed in such settings. Moreover, DFA-alpha1 was calculated using the HRV Logger app, which may present differences in comparison to the industry standard Kubios HRV Software (Biosignal Analysis and Medical Imaging Group, Department of Physics, University of Kuopio, Kuopio, Finland). However, good agreement between both pieces of software has been observed [44].

5. Conclusions

The present study showed that playing the CS:GO game induces significant physiological arousal, manifested by an increase in HR and systolic blood pressure, as well as reduced DFA-alpha1 being a measure of HRV. The CS:GO tournament did not induce changes in blood testosterone and lactate levels in the players.

Changes in physiological and hormonal indices in players while playing CS:GO did not differentiate between winners and losers.

The changes in physiological and hormonal parameters indicate that first-person shooter CS:GO tournaments can be considered a stressor.

Future research should aim to evaluate the elevated physiological stress during live competitive CS:GO tournaments. Those settings may elicit a greater response once there are external stimuli to fully engage the esports players (e.g., prize money or winning the tournament) and greater stress and excitement observed during tournaments. Understanding the physiological response to esports is critical in developing effective training techniques and better preparing esports players for competition. This study can be considered as a basis for future esports investigations.

As physiological characteristics of esports performance remain an understudied area, there is a great demand for further research from sports science and health-oriented perspectives. The physiological responses to esports matches may depend on game type (MOBA vs. FPS vs. RTS) or sex. Women's representation in esports may be described as poor [45], which may cause difficulties in investigating this population, but it does not attenuate the need for such research. Moreover, the application of tools and methods from the field of clinical medicine may be particularly useful, considering esports may be an arrhythmic trigger [46], among other health-related symptoms [47].

Author Contributions: The co-authors contributed to the completion of this article together. Specifically, their individual contribution were as follows: conceptualization, D.S., T.S., K.R., T.K. and J.K.; methodology, D.S., T.S., K.R., T.K. and J.K.; formal analysis, D.S.; investigation, D.S., T.S. and K.R.; data curation, D.S.; writing—original draft preparation, D.S., T.S., K.R., T.K. and J.K.; writing—review and editing, D.S., T.K. and J.K.; visualization, D.S., T.K. and J.K.; and supervision, D.S. All authors have read and agreed to the published version of the manuscript.

Funding: The APC was funded by the Institute of Physical Culture Sciences, the University of Szczecin, Szczecin, Poland, the Institute for Sport—National Research Institute, Warsaw, Poland and the Faculty of Physical Education and Sport in Biała Podlaska, Józef Piłsudski University of Physical Education in Warsaw.

Institutional Review Board Statement: The study protocol was approved by the Institute of Sport—National Research Institute Ethics Committee (approval No. KEBN-23-85-DS).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Acknowledgments: We are grateful to the athletes for participating in this research.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Cunningham, G.B.; Fairley, S.; Ferkins, L.; Kerwin, S.; Lock, D.; Shaw, S.; Wicker, P. ESport: Construct Specifications and Implications for Sport Management. *Sport Manag. Rev.* **2018**, *21*, 1–6. [CrossRef]
2. Newzoo's Global Esports & Live Streaming Market Report 2022 | Free Version. 2022. Available online: https://newzoo.com/resources/trend-reports/newzoo-global-esports-live-streaming-market-report-2022-free-version (accessed on 3 June 2023).
3. Dye, M.W.G.; Green, C.S.; Bavelier, D. The Development of Attention Skills in Action Video Game Players. *Neuropsychologia* **2009**, *47*, 1780–1789. [CrossRef] [PubMed]
4. Green, C.S.; Bavelier, D. Action Video Game Training for Cognitive Enhancement. *Curr. Opin. Behav. Sci.* **2015**, *4*, 103–108. [CrossRef]
5. Greitemeyer, T. The Spreading Impact of Playing Violent Video Games on Aggression. *Comput. Hum. Behav.* **2018**, *80*, 216–219. [CrossRef]
6. Kühn, S.; Kugler, D.T.; Schmalen, K.; Weichenberger, M.; Witt, C.; Gallinat, J. Does Playing Violent Video Games Cause Aggression? A Longitudinal Intervention Study. *Mol. Psychiatry* **2019**, *24*, 1220–1234. [CrossRef]
7. Russoniello, C.V.; Fish, M.; O'Brien, K. The Efficacy of Casual Videogame Play in Reducing Clinical Depression: A Randomized Controlled Study. *Games Health J.* **2013**, *2*, 341–346. [CrossRef]
8. Tortolero, S.R.; Peskin, M.F.; Baumler, E.R.; Cuccaro, P.M.; Elliott, M.N.; Davies, S.L.; Lewis, T.H.; Banspach, S.W.; Kanouse, D.E.; Schuster, M.A. Daily Violent Video Game Playing and Depression in Preadolescent Youth. *Cyberpsychol. Behav. Soc. Netw.* **2014**, *17*, 609–615. [CrossRef]
9. Triberti, S.; Milani, L.; Villani, D.; Grumi, S.; Peracchia, S.; Curcio, G.; Riva, G. What Matters Is When You Play: Investigating the Relationship between Online Video Games Addiction and Time Spent Playing over Specific Day Phases. *Addict. Behav. Rep.* **2018**, *8*, 185–188. [CrossRef]
10. Kumari, L.; Sharma, U.; Singh, S. E-Sports, Anxiety, Aggression and Psychological Well-Being: A Cross-Sectional Study. *J. Clin. Diagn. Res.* **2022**, *16*, VC01–VC06. [CrossRef]
11. Nagorsky, E.; Wiemeyer, J. The Structure of Performance and Training in Esports. *PLoS ONE* **2020**, *15*, e0237584. [CrossRef]
12. Warburton, M.; Campagnoli, C.; Mon-Williams, M.; Mushtaq, F.; Morehead, J.R. Kinematic Markers of Skill in First-Person Shooter Video Games. *PNAS Nexus* **2023**, *2*, pgad249. [CrossRef] [PubMed]

13. Neri, F.; Smeralda, C.L.; Momi, D.; Sprugnoli, G.; Menardi, A.; Ferrone, S.; Rossi, S.; Rossi, A.; Di Lorenzo, G.; Santarnecchi, E. Personalized Adaptive Training Improves Performance at a Professional First-Person Shooter Action Videogame. *Front. Psychol.* **2021**, *12*, 598410. [CrossRef] [PubMed]
14. Laurent, H.K.; Powers, S.I.; Granger, D.A. Refining the Multisystem View of the Stress Response: Coordination among Cortisol, Alpha-Amylase, and Subjective Stress in Response to Relationship Conflict. *Physiol. Behav.* **2013**, *119*, 52–60. [CrossRef]
15. Miller, D.B.; O'Callaghan, J.P. Neuroendocrine Aspects of the Response to Stress. *Metabolism* **2002**, *51* (Suppl 1), 5–10. [CrossRef]
16. Taelman, J.; Vandeput, S.; Spaepen, A.; Van Huffel, S. Influence of Mental Stress on Heart Rate and Heart Rate Variability. In *IFMBE Proceedings, Proceedings of the 4th European Conference of the International Federation for Medical and Biological Engineering, Antwerp, Belgium, 23–27 November 2008*; Vander Sloten, J., Verdonck, P., Nyssen, M., Haueisen, J., Magjarevic, R., Nagel, J.H., Eds.; Springer: Berlin/Heidelberg, Germany, 2009; Volume 22, pp. 1366–1369. [CrossRef]
17. Sousa, A.; Ahmad, S.L.; Hassan, T.; Yuen, K.; Douris, P.; Zwibel, H.; DiFrancisco-Donoghue, J. Physiological and Cognitive Functions Following a Discrete Session of Competitive Esports Gaming. *Front. Psychol.* **2020**, *11*, 1030. [CrossRef] [PubMed]
18. Gray, P.B.; Vuong, J.; Zava, D.T.; McHale, T.S. Testing Men's Hormone Responses to Playing League of Legends: No Changes in Testosterone, Cortisol, DHEA or Androstenedione but Decreases in Aldosterone. *Comput. Hum. Behav.* **2018**, *83*, 230–234. [CrossRef]
19. Schmidt, S.C.E.; Gnam, J.-P.; Kopf, M.; Rathgeber, T.; Woll, A. The Influence of Cortisol, Flow, and Anxiety on Performance in E-Sports: A Field Study. *BioMed Res. Int.* **2020**, *2020*, 9651245. [CrossRef]
20. Kraemer, W.J.; Caldwell, L.K.; Post, E.M.; Beeler, M.K.; Emerson, A.; Volek, J.S.; Maresh, C.M.; Fogt, J.S.; Fogt, N.; Häkkinen, K.; et al. Arousal/Stress Effects of "Overwatch" ESports Game Competition in Collegiate Gamers. *J. Strength Cond. Res.* **2022**, *36*, 2671–2675. [CrossRef]
21. Melillo, P.; Bracale, M.; Pecchia, L. Nonlinear Heart Rate Variability Features for Real-Life Stress Detection. Case Study: Students under Stress Due to University Examination. *Biomed. Eng. Online* **2011**, *10*, 96. [CrossRef]
22. Marques, A.H.; Silverman, M.N.; Sternberg, E.M. Evaluation of Stress Systems by Applying Noninvasive Methodologies: Measurements of Neuroimmune Biomarkers in the Sweat, Heart Rate Variability and Salivary Cortisol. *Neuroimmunomodulation* **2010**, *17*, 205–208. [CrossRef]
23. Castaldo, R.; Melillo, P.; Bracale, U.; Caserta, M.; Triassi, M.; Pecchia, L. Acute Mental Stress Assessment via Short Term HRV Analysis in Healthy Adults: A Systematic Review with Meta-Analysis. *Biomed. Signal Process. Control* **2015**, *18*, 370–377. [CrossRef]
24. Gündoğdu, S.; Çolak, Ö.H.; Polat, Ö. Investigation of the Effect of ESport on HRV Signal by Using Poincaré Plot Analysis. *Trait. Signal* **2022**, *39*, 589–594. [CrossRef]
25. Shaffer, F.; Ginsberg, J.P. An Overview of Heart Rate Variability Metrics and Norms. *Front. Public Health* **2017**, *5*, 258. [CrossRef] [PubMed]
26. Rogers, B.; Giles, D.; Draper, N.; Hoos, O.; Gronwald, T. A New Detection Method Defining the Aerobic Threshold for Endurance Exercise and Training Prescription Based on Fractal Correlation Properties of Heart Rate Variability. *Front. Physiol.* **2020**, *11*, 596567. [CrossRef] [PubMed]
27. Leis, O.; Lautenbach, F. Psychological and Physiological Stress in Non-Competitive and Competitive Esports Settings: A Systematic Review. *Psychol. Sport Exerc.* **2020**, *51*, 101738. [CrossRef]
28. Van Paridon, K.N.; Timmis, M.A.; Nevison, C.M.; Bristow, M. The Anticipatory Stress Response to Sport Competition; a Systematic Review with Meta-Analysis of Cortisol Reactivity. *BMJ Open Sport Exerc. Med.* **2017**, *3*, e000261. [CrossRef]
29. Carrasco Páez, L.; Martínez-Díaz, I.C. Training vs. Competition in Sport: State Anxiety and Response of Stress Hormones in Young Swimmers. *J. Hum. Kinet.* **2021**, *80*, 103–112. [CrossRef]
30. Mendoza, G.; Clemente-Suárez, V.J.; Alvero-Cruz, J.R.; Rivilla, I.; García-Romero, J.; Fernández-Navas, M.; de Albornoz-Gil, M.C.; Jiménez, M. The Role of Experience, Perceived Match Importance, and Anxiety on Cortisol Response in an Official Esports Competition. *Int. J. Environ. Res. Public. Health* **2021**, *18*, 2893. [CrossRef]
31. Aliyari, H.; Sahraei, H.; Daliri, M.R.; Minaei-Bidgoli, B.; Kazemi, M.; Agaei, H.; Sahraei, M.; Seyed Hosseini, S.M.A.; Hadipour, M.M.; Mohammadi, M.; et al. The Beneficial or Harmful Effects of Computer Game Stress on Cognitive Functions of Players. *Basic Clin. Neurosci.* **2018**, *9*, 177–186. [CrossRef]
32. Watanabe, K.; Saijo, N.; Minami, S.; Kashino, M. The Effects of Competitive and Interactive Play on Physiological State in Professional Esports Players. *Heliyon* **2021**, *7*, e06844. [CrossRef]
33. Andre, T.L.; Walsh, S.M.; ValladÃo, S.; Cox, D. Physiological and Perceptual Response to a Live Collegiate Esports Tournament. *Int. J. Exerc. Sci.* **2020**, *13*, 1418–1429. [PubMed]
34. Ballard, M.E.; Hamby, R.H.; Panee, C.D.; Nivens, E.E. Repeated Exposure to Video Game Play Results in Decreased Blood Pressure Responding. *Media Psychol.* **2006**, *8*, 323–341. [CrossRef]
35. Siervo, M.; Sabatini, S.; Fewtrell, M.S.; Wells, J.C.K. Acute Effects of Violent Video-Game Playing on Blood Pressure and Appetite Perception in Normal-Weight Young Men: A Randomized Controlled Trial. *Eur. J. Clin. Nutr.* **2013**, *67*, 1322–1324. [CrossRef] [PubMed]
36. Chaput, J.-P.; Visby, T.; Nyby, S.; Klingenberg, L.; Gregersen, N.T.; Tremblay, A.; Astrup, A.; Sjödin, A. Video Game Playing Increases Food Intake in Adolescents: A Randomized Crossover Study. *Am. J. Clin. Nutr.* **2011**, *93*, 1196–1203. [CrossRef] [PubMed]

37. Kindermann, H.; Javor, A.; Reuter, M. Playing Counter-Strike versus Running: The Impact of Leisure Time Activities and Cortisol on Intermediate-Term Memory in Male Students. *Cogn. Syst. Res.* **2016**, *40*, 1–7. [CrossRef]
38. Ayhan, S. The Effect of E-Sports Games on Stress Hormones and Biochemical Parameters of Athletes. *Pak. J. Med. Health Sci.* **2022**, *16*, 406. [CrossRef]
39. Mazur, A.; Susman, E.J.; Edelbrock, S. Sex Difference in Testosterone Response to a Video Game Contest. *Evol. Hum. Behav.* **1997**, *18*, 317–326. [CrossRef]
40. DiFrancisco-Donoghue, J.; Balentine, J.; Schmidt, G.; Zwibel, H. Managing the Health of the ESport Athlete: An Integrated Health Management Model. *BMJ Open Sport Exerc. Med.* **2019**, *5*, e000467. [CrossRef]
41. Clements, A.J.; Paul, R.W.; Lencer, A.J.; Seigerman, D.A.; Erickson, B.J.; Bishop, M.E. Analysis of Musculoskeletal Injuries Among Collegiate Varsity Electronic Sports Athletes. *Cureus* **2022**, *14*, e31487. [CrossRef]
42. Clevenger, K.A.; Howe, C.A. Energy Cost and Enjoyment of Active Videogames in Children and Teens: Xbox 360 Kinect. *Games Health J.* **2015**, *4*, 318–324. [CrossRef]
43. Graves, L.E.F.; Ridgers, N.D.; Williams, K.; Stratton, G.; Atkinson, G.; Cable, N.T. The Physiological Cost and Enjoyment of Wii Fit in Adolescents, Young Adults, and Older Adults. *J. Phys. Act. Health* **2010**, *7*, 393–401. [CrossRef] [PubMed]
44. Gronwald, T.; Berk, S.; Altini, M.; Mourot, L.; Hoos, O.; Rogers, B. Real-Time Estimation of Aerobic Threshold and Exercise Intensity Distribution Using Fractal Correlation Properties of Heart Rate Variability: A Single-Case Field Application in a Former Olympic Triathlete. *Front. Sports Act. Living* **2021**, *3*, 668812. [CrossRef] [PubMed]
45. Ruvalcaba, O.; Shulze, J.; Kim, A.; Berzenski, S.R.; Otten, M.P. Women's Experiences in ESports: Gendered Differences in Peer and Spectator Feedback During Competitive Video Game Play. *J. Sport Soc. Issues* **2018**, *42*, 295–311. [CrossRef]
46. Lawley, C.M.; Tester, M.; Sanatani, S.; Prendiville, T.; Beach, C.M.; Vinocur, J.M.; Horie, M.; Uhm, J.-S.; Khongphatthanayothin, A.; Ayers, M.D.; et al. Life-Threatening Cardiac Arrhythmia and Sudden Death during Electronic Gaming: An International Case Series and Systematic Review. *Heart Rhythm* **2022**, *19*, 1826–1833. [CrossRef] [PubMed]
47. Monteiro Pereira, A.; Costa, J.A.; Verhagen, E.; Figueiredo, P.; Brito, J. Associations Between Esports Participation and Health: A Scoping Review. *Sports Med.* **2022**, *52*, 2039–2060. [CrossRef] [PubMed]