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Physiological demand of esports athletes

Herdiansyah Agus[1*], Maleaky Patty[2], Eko Putra Utama.J[2], Dito Dwi Cahyo[1], Yudhi Esa Saputra[3], Bayu Santoso[4], Hadiat Aliansyah[1]

[1]Pendidikan Kepelatihan Olahraga, Fakultas Pendidikan Olahraga dan Kesehatan, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudhi No. 229, Kota Bandung, Jawa Barat, Indonesia.
[2]Pendidikan Jasmani, Fakultas Keguruan dan Ilmu Pendidikan, Universitas Dehasen, Jl. Meranti Raya No.32, Kota Bengkulu, Bengkulu, Indonesia.
[3]Pendidikan Kepelatihan Olahraga, Fakultas Keguruan Ilmu Pendidikan, Universitas Tangerang Raya, Perumahan Sudirman Indah Blok E, Kabupaten Tangerang, Banten, Indonesia.
[4]Kepelatihan Fisik Olahraga, Fakultas Pendidikan Olahraga dan Kesehatan, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudhi No. 229, Kota Bandung, Jawa Barat, Indonesia.
[*]Corresponding Author. Email: herdiansyah.agus@upi.edu

Abstract

This study aims to reveal the physiological demands on esports athletes when competing. To achieve this goal, a literature review was conducted on Scopus databases using Specific inclusion criteria between 2006 and 2024. 5 articles were selected for this review based on the relevance of the topics reviewed. Based on the articles, for esports athletes, it was found that the maximum oxygen uptake demand was 41.98 ± 5.50 mL/kg/min or the highest up to 48 mL/kg/min, while the demand for oxygen consumption at gameplay was found at an average of 3.89 mL/kg or a median of 0.29 (0.24-0.35) L/min. Furthermore, the maximum heart rate was 191 ± 10 beats/min (at aerobic maximum test) or 136.8 ± 13.3 beats/min (at gameplay). While the average heart rate when playing the game was between the median 87.1 (80.3 - 104) beats/min to the average 110.1 ± 15.7 beats/min. Based on this data, it can be understood the physiological response of esports athletes in game situations, which can be adjusted later to the dose of training provided (athlete adaptation to match needs). In addition, data on the physiological demands of esports athletes can also be used as a minimum target for the ability of esports athletes to be used as a benchmark. To prepare athletes to be physiologically ready for the match.

Keywords: Physiological, Esports, Esports Athlete, Demand, Heart Rate, Oxygen Uptake.

INTRODUCTION

Esports are known as competitive or organized activities, made possible by technology (digital), which encompass various levels of physicality, virtuality, and technological involvement (Nagorsky, E. & Wiemeyer, J., 2020; McGee, C. et al, 2021). Esports can be differentiated into specific genres such as Multiplayer Online Battlefield Arena (MOBA), First Person Shooters (FPS), Real Time Strategy (RTS), and sport simulations. In every genre, there are different digital games, with different mechanics and competition rules that have to be mastered by the players (Nagorsky, E. & Wiemeyer, J., 2020).

The development of esports in the world continues to increase, recorded in 2015 the esports audience was estimated at 235 million users, continuing to increase to 295 million in 2018 (Nagorsky, E. & Wiemeyer, J., 2020). Even in 2019, it was recorded that esports competitions received 450 million viewers worldwide (McGee, C. et al, 2021). With a market value of more than 3.5 billion dollars by 2025 (Kraemer, W. J. et al., 2022). The rapid development, both from the number of users and viewers, in terms of the value of the world market, must be an important note for policy makers, academics, and everyone involved in its development. How this sport should be developed with strong and up-to-date scientific studies.

In relation to sports, the position of esports must be strong in concept and on a physiological basis. Although among researchers and sports practitioners there are still many who debate esports as a sport,

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Frączek, B., in his research states that esports is still the same sport as other traditional sports, which still has a domain of physical ability and fitness (Frączek, B. et al, 2024). Professional esports athletes perform 10 movements per second, 500 to 600 movements per minute, which are performed within a training duration (esports-related skills) of 5 to 10 hours per day on a regular basis (McGee, C. et al, 2021). The total training load of professional esport athletes per day can reach 8000 to 11.000 keystrokes (McGee, C. et al., 2021). This is because esports are designed to be played competitively, unlike traditional video games, which are designed to be played casually (Nicholson, M. et al, 2024).

The amount of training load and biomotor activity carried out by professional esports athletes, of course, requires certain physiological demands to support their activities. In line with other traditional sports that require physical abilities to support performance (Bais, S. et al, 2024), esports also requires physical ability and fitness, which will affect its success (Frączek, B. et al, 2024). Even in terms of physical and physiological demands, esport athletes are known to be 3 times higher than office workers (depending on the type of game played, platform, and performance label) (McGee, C. et al, 2021). Especially in relation to the number of biomotor actions performed, oxygen uptake, and heart rate during competition.The higher the gaming competition (elite), the higher the physical and physiological activity demands, as evidenced by heart rates and levels of cortisol measured during competition (Toth, A. J. et al, 2020). This is related to the increased challenge of playing games at higher ranks or competitive levels (García Bastida, J. et al, 2024).

The importance of knowledge and data related to the physiological abilities of esports athletes is not in line with the availability of references that have been published at this time. In terms of research on the physical fitness of esports athletes, it is noted that it is very limited (Frączek, B. et al, 2024), and there is also very little knowledge related to physical health in esports (McGee, C. et al, 2021). In particular, the physiological demands of esports are poorly understood, so there is a need for further study (Nicholson, M. et al, 2024). So that it can be used as a guideline for training esports athletes in the future, to improve performance and improve athlete health. For this reason, this research will conduct a literature study on the physiological demands of esports athletes.

METHOD

The Scopus databases were searched using specific inclusion criteria included (1) physiological demand, (2) esports, and (3) athletes. Specific criteria were used to find articles that truly matched the objectives of this study.. The search includes literature from 2006 to 2024. This research was conducted on articles from 2006 to 2024. This was done because the purpose of this research was to reveal the physiological demands of esports athletes during competition. 2006 was the year when the competitive esports ecosystem developed globally. In that year, several esports federations (such as the G7 teams federation) and professional teams were formed, competitive world events (such as the Worldwide Webgames Championship, World Cyber Games, and others) were held, and Major League Gaming was broadcast live on American television for the first time. Therefore, it is appropriate to search for research results from 2006.

The search found 7 research documents based on title and abstract. Then, screening was conducted based on the overall content of the research, which was truly related to the research objective (physiological demands of esports athletes during competition). As a result of the screening, 4 articles were chosen for this review based on the relevance of the reviewed topic.

Tabel 1. Articles Description

Authors (year)	Participant Demographics	Method	Games	Journal
Kraemer et al. (2022)	Thirty-two male college-aged gamers (age: 21.3 ± 2.7 years; range 18–32 years; estimated time played per week: 18 ± 15 hours)	Comparative study	Overwatch (Blizzard Entertainment, Irvine, CA)	Journal of Strength and Conditioning Research
Sousa et al., (2020)	Subjects were recruited from the student population at NYIT, Old Westbury, NY, United States.	Prospective observational cohort study	First-person shooter (FPS), Multiplayer	Frontiers in Psychology

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	Participants aged between 18 and 30 years old Average age was 20 years (SD = 1.82 years) Gender 100% Male Subjects' gaming sessions lasted on average 151 min (SD = 49 min)		Online Battle Arena (MOBA)	
Frączek, B., et al. (2024)	196 elite Polish male eSports players with at least 2 years of gaming experience (average 6.4±2.6 years) 19.9% of the participants had professional experience and 80.1% are semi-professional	Cross-sectional design	Counter-Strike Global Offensive (CS:GO), League of Legends (LoL), and StarCraft	Physical Activity Review
Nicholson et al. (2024)	Participants were recruited from a local intervarsity esports academy, which competes within the national intervarsity league, with some individuals also competing within professional leagues. Participants are required to be ranked within the top 10% of their game. Age = 20.7 ± 2.69 years Height = 183 ± 2,69 cm Weight = 82,1 ± 18,6 kg BMI = 24.6 ± 5.89 $kg \cdot m^{-2}$	Comparative study	Rocket League. League of Legends, Overwatch, Valorant, Counter Strike: Global Offensive	Sports Medicine

RESULTS AND DISCUSSION

In competition, esports have unique characteristics and physiological demands. Because esports are still sports like other traditional sports, which require physical ability and fitness (Frączek, B. et al, 2024). It is even said to be three times greater than office workers (McGee, C. et al, 2021). So it can help and influence the success of professional esports athletes (Frączek, B. et al, 2024).

Based on the analysis conducted on the results of previous research, two main domains were found to be studied within the scope of the physiological demands of esports athletes, namely the Oxygen uptake and heart rate domains. This is in line with the results of research from several decades ago, precisely in 1983, that playing games will increase cardiovascular demands (Gwinup, G., Haw, T., & Elias, A., 1983). By paying attention to this, it will certainly encourage esports athletes to good health, good performance, and success for the athletes (esports athletes).

Tabel 2. Data reviewed by 4 articles

Domain	Result	Test	Reference
Oxygen uptake	VO2max (maximum oxygen uptake), mean = 41.98±5.50 mL/kg/min	Monark 894E cycle ergometer test	Frączek, B., et al. (2024)
	VO2 (Oxygen consumption) at gameplay, median = 0.29 (0.24–0.35)	ECG equipment (Custo-Cardio 300)	Nicholson et al. (2024)
Heart Rate	Maximum HR 191±10 beats/min HR at Aerobic Threshold 146.20±6.94 beats/min	Using Pulse oxymeter (Polar Electro, model S410)	Frączek, B., et al. (2024)

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	HR at Anaerobic Threshold 174.16±7.87 beats/min	at Monark 894E cycle ergometer test	
	HR at gameplay, median = 87.1 (80.3 – 104)	5-lead ECG	Nicholson et al. (2024)
	Maximum HR = 136.8 ± 13.3 beats/min Average HR = 110.1 ± 15.7 beats/min	Polar H10 chest strap (Polar Electro Inc., Lake Success, NY)	Kraemer et al. (2022)
	HR pregaming 78 HR postgaming 84		Sousa et al., (2020)

Oxygen Uptake

The physiological demands of esports athletes in the oxygen uptake domain focus on maximum oxygen uptake (VO2max) and oxygen consumption during gameplay (VO2) (Frączek, B. et al, 2024; Nicholson, M. et al. 2024; Sousa, A. et al., 2020). In VO2max, the average maximum oxygen consumption ability of esports athletes ranges from 41.98 ± 5.50 mL/kg/min (Frączek, B. et al, 2024), with the highest group having VO2max up to 38-48 mL/kg/min (Alam, R. R. I., Rahayu, S., & Raharjo, A. 2023). Oxygen consumption during gameplay (VO2) was found at an average of 3.89 ml/kg or a median of 0.29 (0.24-0.35) L/min (Nicholson, M. et al, 2024).

Maximum oxygen uptake (VO2max) is the maximum amount of oxygen that can be consumed by the body. In the study of Frączek, B., et al. (Frączek, B. et al, 2024), an analysis was conducted on 196 professional esports athletes in Poland, who had an average gaming experience of 6.4±2.6 years in the games Counter-Strike Global Offensive (CS:GO), League of Legends (LoL), and StarCraft. The study shows that esports athletes have an average maximum oxygen uptake ability of 41.98 ± 5.50 mL/kg/min (Frączek, B. et al, 2024). Research by Alam et al., analyzed 160 esports athletes in Palu City, Indonesia. The athletes were involved in PUBG Mobile, Mobile Legends, and Free Fire games. The results showed that the group with the highest maximum oxygen uptake ranged from 38 to 48 mL/kg/min (Alam, R. R. I. et al, 2023). The highest group consisted of only 4 athletes out of 166 people. While the largest group of athletes (122 people) were in the middle group with maximum oxygen uptake ranging from 31 to 37 mL/kg/min.

The maximum oxygen uptake of esports athletes is at an average level based on the standards of the American College of Sports Medicine and the American Heart Association (Fletcher, G. F. et al., 2001) and the standards of Finnish men aged 20 to 29 years (Vähä-Ypyä, H. et al. 2021). Higher or better than the average VO2max of young people with sedentary lifestyles (33.6±5.4 mL/kg/min) (Farland, C. V. et al., 2015). However, it is lower than that of young people with an active lifestyle (recreational sports 4 times a week) (45±8 mL/kg/min) (Hodgson, M. D. et al. 2018) and athletes at universities (52.9±4.7 mL/kg/min) (Tabata, I. et al. 1996). However, these comparisons were made in general terms. For a more accurate understanding, it is necessary to pay attention to the test instruments used (the same test instruments) (Frączek, B. et al, 2024).

Oxygen consumption during gameplay (VO2) is the amount of oxygen consumed by the body while playing games. Nicholson et al. (2024) involved participants from a local intervarsity esports academy, which competes within the national intervarsity league, with some individuals also competing within professional leagues. Participants were limited to those ranked in the top 10% of each game (Rocket League, League of Legends, Overwatch, Valorant, Counter-Strike: Global Offensive). The average age of participants was 20.7 ± 2.69 years, with a height of 183 ± 2.69 cm and a body weight of 82.1 ± 18.6 kg, and a BMI of 24.6 ± 5.89 kg·m^(-2). The study found that oxygen consumption during gameplay (VO2) averaged 3.89 ml/kg, or at a median of 0.29 L/min, with data collected in the range of 0.24 L/min to 0.35 L/min (Nicholson, M. et al, 2024).

Oxygen consumption during gaming is higher (median 0.29 L/min) than at rest (median 0.27 L/min) (Nicholson, M. et al, 2024). This is related to increased action per minute and increased metabolic equivalents (METs) (Kocak, U. Z., 2022). In fact, several studies have found that players of MOBA games (multiplayer online battle arena) expend 40% more energy than those who do not play games (resting/not engaging in physical activity) (Nicholson, M. et al, 2024).

Heart Rate

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For the heart rate domain on the physiological demands of esports athletes focus on maximum heart rate, heart rate at aerobic threshold, heart rate at anaerobic threshold, average heart rate, heart rate at gameplay, heart rate before and after gameplay (Kraemer, W. J. et al., 2022; Frączek, B. et al, 2024; Nicholson, M. et al, 2024; Alam, R. R. I., Rahayu, S., & Raharjo, A., 2023). The maximum heart rate of esports athletes ranges from 191±10 beats/min (Frączek, B. et al, 2024) or 136.8 ± 13.3 beats/min (Kraemer, W. J. et al., 2022). While heart rate at aerobic threshold is 146.20±6.94 beats/min, and heart rate at anaerobic threshold is 174.16±7.87 beats/min (Frączek, B. et al, 2024). Heart rate during game play was at a median of 87.1 (80.3 - 104) beats/min (Nicholson, M. et al, 2024). Heart rate before the game averaged 78 beats/min, and after the game averaged 84 beats/min (Sousa, A. et al, 2020).

Maximum heart rate is the highest amount of heart rate an athlete can achieve during a specific activity. The study of Frączek, B., et al. (Frączek, B. et al, 2024) on 196 esports athletes with the demographics previously described, found that the maximum heart rate of esports athletes was 191±10 beats/min (Frączek, B. et al, 2024). Heart rate data was collected using a Pulse oxymeter (Polar Electro, model S410), which was taken while the athlete was performing the Monark 894E cycle ergometer test. Different things were found in research conducted by Kraemer et al. (2022). In their research, it was found that the maximum heart rate of esports athletes was 136.8 ± 13.3 beats/min (Kraemer, W. J. et al., 2022). Heart rate data was taken using a Polar H10 chest strap (Polar Electro Inc., Lake Success, NY), but under different conditions, namely when athletes play games. Data was collected on 32 university-level male athletes. With an average age of 21.3 ± 2.7 years, which ranged from 18 to 32 years, who played games an average of 18 ± 15 hours per week.

There is a striking difference between the results of research conducted by Frączek, B., et al. (Frączek, B. et al, 2024) and research conducted by Kraemer et al. (Kraemer, W. J. et al., 2022). Frączek found that the maximum heart rate in esports athletes was 191±10 beats/min. Kraemer found that the maximum heart rate in esports athletes was 136.8 ± 13.3 beats/min. This difference is quite large, even up to 28% more. This happens because in Frączek's research, the maximum heart rate was taken when the participants were doing the Monark 894E cycle ergometer test. This demands the maximum ability of athletes to do physical activity. Whereas in Kraemer's study, the maximum heart rate was taken when participants were playing the Overwatch game (Blizzard Entertainment, Irvine, CA). which is natural, because the game played and the duration of the game affect the number of heartbeats (Sousa, A. et al, 2020; Fletcher, G. F. et al, 2001). So it is very logical that there is a significant difference between the two research results.

Heart rate at aerobic threshold and heart rate at anaerobic threshold are the number of heart rates an athlete reaches when the energy system is at aerobic threshold and anaerobic threshold. The study of Frączek, B., et al. (Frączek, B. et al, 2024) found that the heart rate of esports athletes at the aerobic threshold was 146.20±6.94 beats/min, while the heart rate of esports athletes at Anaerobic Threshold was 174.16±7.87 beats/min (Frączek, B. et al, 2024). The heart rate data was taken using a pulse oxymeter (Polar Electro, model S410), which was taken when the athlete was doing the Monark 894E cycle ergometer test. There is quite a difference, heart rate at aerobic threshold and anaerobic threshold, there is a difference of about 16%.

Heart rate at gameplay is the number of pulse-beats an esports athlete achieves during gameplay. Nicholson et al. (Frączek, B. et al, 2024) involving participants from a local intervarsity esports academy, with the demographics previously described, found that the heart rate of esports athletes during gameplay was at a median of 87.1 beats/min, with a range of 80.3 beats/min to 104 beats/min (Nicholson, M. et al, 2024). This data was collected from athletes while playing the games Counter-Strike Global Offensive (CS:GO), League of Legends (LoL), and StarCraft, using a 5-lead ECG. While the results of research by Kraemer et al. (2022) in participants with the demographics previously described obtained higher heart rate results. The average was 110.1 ± 15.7 beats/min while playing the game (Kraemer, W. J. et al., 2022). Throughout the game, heart rate averaged 54% of maximal heart rate (predicted by age), with a range between 40% and 70% of maximal heart rate (Kraemer, W. J. et al., 2022).

The difference in average heart rate during gameplay is, of course, directly related to the differences in the participants studied. Especially seen from the games played by the participants, in the study of Nicholson et al. the games played were Counter-Strike Global Offensive (CS: GO), League of Legends (LoL), and StarCraft (Nicholson, M. et al. 2024). Whereas in Kraemer et al.'s research, the game played was Overwatch (Blizzard Entertainment, Irvine, CA) (Kraemer, W. J. et al., 2022). The difference in the game played, even the duration of the game played, has an effect on the difference in

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heart rate (Sousa, A. et al., 2020; Fletcher, G. F. et al., 2001). However, one thing in common in these studies is that the pulse rate when playing games will increase or be higher than the heart rate during normal daily activities or rest (Kraemer, W. J. et al., 2022; Nicholson, M. et al, 2024; Gwinup, G., Haw, T., & Elias, A. 1983; Fletcher, G. F. et al., 2001). This is due to increased arousal, visual stimulation, action rate per minute, METs, as well as emotional responses in games that stimulate sympathetic impulses for increased heart rate (Kocak, U. Z., 2022; Porter, A. M., & Goolkasian, P., 2019).

Pregaming heart rate is the average number of athletes' heart rates before playing the game, while postgaming heart rate is the average number of athletes' heart rates after playing the game. The Sousa et al. study (2020) was conducted on the student population at NYIT, Old Westbury, NY, United States. The average participant age was 20 years (SD = 1.82 years), and the distribution was between 18 and 30 years. The gender of the participants was 100% male. And the participants played the game on average 151 min (SD = 49 min). It was found that the athletes' average heart rate before gaming was 78 beats/min. The average heart rate of athletes after playing the game is at 84 beats/min (Sousa, A. et al, 2020). Based on this study, there was a difference in heart rate between pregaming and postgaming of around 7.1%, which naturally increases due to excitement, visual stimulation, and emotional responses (Porter, A. M., & Goolkasian, P., 2019). In addition, the more competitive the game played (high level or elite), the more challenging it will be for users (increased heart rate) (García Bastida, J. et al, 2024). However, based on statistical tests conducted, there is no significant difference between the heart rate of esports athletes before and after playing the game (Sousa, A. et al., 2020). This study was conducted on athletes who played First-person shooter (FPS) and Multiplayer Online Battle Arena (MOBA) games.

CONCLUSION

The relatively passive physical activity of esports gaming is thought to result in little or no physiological demand. This study found, however, that there is strong evidence of unique physiological characteristics in gaming. The main physiological demands in several studies relate to oxygen uptake (maximum oxygen uptake and oxygen consumption during gameplay) and heart rate (maximum heart rate, heart rate at Aerobic Threshold, heart rate at Anaerobic Threshold, Average heart rate, heart rate at game play, heart rate before and after game play). For esports athletes, the maximum oxygen uptake demand was found to be 41.98±5.50 mL/kg/min or the highest to 48 mL/kg/min, while the oxygen consumption demand at gameplay was found to be an average of 3.89 mL/kg or a median of 0.29 (0.24-0.35) L/min. Furthermore, the demand at maximum heart rate was 191 ± 10 beats/min (at maximum test) or 136.8 ± 13.3 beats/min (at gameplay). While the average heart rate during gameplay was between a median of 87.1 (80.3 - 104) beats/min and a mean of 110.1 ± 15.7 beats/min. Understanding physiological responses in game situations, or physiological demand, is the first and most important step in preparing athletes for competition. It is recommended for esports athletes' physical and fitness coaches to pay attention to these physiological demands. It can even be used as a benchmark, either as a target goal or output of training, it can also be used as a basis for the creation and monitoring of planned and implemented training. For the sake of research continuity and scientific development, further research is needed to examine how physiological demands on esports athletes relate to the training (especially physical training) undertaken by athletes.

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