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# The Arousal/Stress Effects of “Overwatch” eSport Game Competition in Collegiate Gamers

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**The Arousal/Stress Effects of “Overwatch” eSport Game Competition in Collegiate Gamers**

## 1 **Abstract**

2 To date no physical response data are available for one of the most popular eSport games,  
3 *Overwatch*. The purpose of this investigation was to describe the stress signaling associated with  
4 competitive *Overwatch* play and to understand how acute hormonal responses may impact  
5 performance. Thirty-two male college-aged gamers (Age:  $21.3 \pm 2.7$  years; estimated time played  
6 per week:  $18 \pm 15$  hours) completed the study. Subjects were randomly assigned to a six-player  
7 team to compete in a tournament-style match. Salivary measures of cortisol and testosterone were  
8 collected immediately before (PRE) and after (POST) the first-round game, with heart rate  
9 recorded continuously during the match. Mean characteristics were calculated for each variable  
10 and comparisons made by skill level. Significance was defined as  $P \leq 0.05$ . There were no  
11 differences in measures of salivary cortisol. A differential response pattern was observed by skill  
12 level for testosterone. The low skill group displayed a significant increase in testosterone with  
13 game play (mean  $\pm$ SD, testosterone PRE:  $418.3 \pm 89.5$  pmol $\cdot$ L $^{-1}$ , POST:  $527.6 \pm 132.4$  pmol $\cdot$ L $^{-1}$ ,  
14  $P < 0.001$ ), while no change was observed in the high skill group. There were no differences in heart  
15 rate characteristics between skill groups. Overall, average heart rate was  $107.2 \pm 17.8$  bpm with  
16 an average max heart rate of  $133.3 \pm 19.1$  bpm. This study provides unique physiological evidence  
17 that a sedentary *Overwatch* match modulates endocrine and cardiovascular responses, with skill  
18 level emerging as a potential modulator.

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20 **Key Words:** video games, heart rate, endocrine, cortisol, testosterone,

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## 1 INTRODUCTION

2 Globally, competitive electronic gaming (eSports) is gaining traction as a recognized sport.  
3 Market research indicates that the eSport industry will be worth more than 3.5 billion dollars by  
4 2025—representing a growth of 70% over the next four years (7). The drastic increase is attributed  
5 to the emergence of streaming platforms and associated advertisement and high-value sponsorship  
6 deals. In 2021, the Olympic Council of Asia announced that eight eSport games (*League of*  
7 *Legends, Hearthstone, Dota 2, Street Fighter V, Arena of Valor, Dream Three Kingdoms 2, FIFA*  
8 *and PUBG Mobile*) will be official events at the 2022 Asian Games in Hangzhou—awarding  
9 medals alongside more traditional sporting events such as archery, baseball, cycling, track and  
10 martial arts (25). Whether the sport will be included as an official event at the 2028 Olympic  
11 Games in Los Angeles continues to draw speculation. However, inclusion seems plausible given  
12 that the International Olympic Committee launched the first ever Olympic-licensed virtual sporting  
13 event—The Virtual Series—ahead of the 2020 Summer Games in Tokyo (2).

14  
15 The growth of the industry is not limited to the professional arena. One of the most rapidly  
16 evolving areas of eSport has been the rise of collegiate gaming. In 2016, The National Association  
17 of Collegiate Esports (NACE) was formed in the United States. At the time of its formation, there  
18 were just seven colleges and universities offering varsity eSport programs (<https://nacesports.org/>  
19 May 6, 2022). As of 2022, there are more than 170 officially recognized varsity eSport programs  
20 in the U.S. According to the NACE directory, the three most popular games at the collegiate level  
21 are *League of Legends, Overwatch* and *Rocket League*, with more than 115 programs listing each  
22 game as part of their member profile ([https://members.nacesports.org/AF\\_MemberDirectory.asp](https://members.nacesports.org/AF_MemberDirectory.asp)  
23 May 6, 2022).

1           Mirroring this increasing popularity, scientists have become interested in studying eSport  
2 athletes to understand the stress of the competitive and noncompetitive environments (13). Many  
3 have had serious concerns regarding a variety of health issues resulting from the long sedentary  
4 demands and psychological stress of intense gaming practice and participation (27). To date, the  
5 study of eSport has primarily focused on *League of Legends* due to its popularity in the gaming  
6 community (8). However, a recent study by Sousa et al (23), highlights the need for studying a  
7 variety of gaming contexts given that first-person shooter (FPS) games, such as *Overwatch*, appear  
8 to elicit a greater sympathetic nervous system response than multiplayer online battle area  
9 (MOBA) games such as *League of Legends* (23). This may partially explain the varied findings  
10 observed for stress responses during competitive eSport play with some displaying increases (17,  
11 19), decreases (1) or no changes (8, 17) in measures of salivary cortisol. Interestingly, expert  
12 gamers appear to respond differently than novice players, yet the influence of game skill ranking  
13 on hormonal response patterns has yet to be evaluated. Given the lack of data on this emerging  
14 sport, there is a need to explore the physiological demands of eSport competition and to understand  
15 how acute hormonal responses may impact performance. The purpose of this study was to examine  
16 the physiological stress responses of college aged gamers during a laboratory-controlled  
17 *Overwatch* competition. We hypothesized that player skill level would influence biomarkers of  
18 stress (cortisol, testosterone, heart rate) due to the anxiety and arousal associated with competitive  
19 performance (17, 19).

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## 1 **METHODS**

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### 3 ***Experimental Approach to the Problem***

4 Biomarkers were assessed surrounding the first round of a tournament-style *Overwatch*  
5 (Blizzard Entertainment, Irvine, CA) match. Subjects were randomly assigned to a six-player team  
6 to compete in the multiplayer first-person shooter game. We examined the acute physiological  
7 responses to a single game of *Overwatch* in a team competition set up in a laboratory setting.  
8 Salivary measures, for the assessment of cortisol and testosterone, were collected immediately  
9 before (PRE) and after (POST) the first-round game. Heart rate was recorded continuously to  
10 assess cardiovascular arousal during game play.

### 11 ***Subjects***

12 Thirty-two male gamers (Mean  $\pm$  SD, age: 21.3  $\pm$  2.3 years; estimated time played per  
13 week: 18  $\pm$  15 hours) participated in this study. The study was approved by the institutional review  
14 board for use of human subjects at The Ohio State University. Each subject gave written informed  
15 consent after having the risks and benefits of the study explained. Subjects were recruited from  
16 the collegiate population of students and the surrounding community (>18 years old). All subjects  
17 had some experience playing *Overwatch* whether recreationally or competitively. All subjects  
18 were asked to self-report their rank in *Overwatch*. High rank players were defined as those self-  
19 ranked diamond and above (skill ranking  $\geq$  3000; top ~20% of *Overwatch* players) while low rank  
20 players were defined as those self-ranked platinum and below (skill ranking < 3000; bottom ~80%  
21 of *Overwatch* players).

### 22 ***Procedures***

23 All subjects were tested during the initial game of the tournament competition. Each  
24 subject was tested pre to post 1<sup>st</sup> game (i.e., 16-25 min) within the afternoon competition structure

1 (1300 to 1530). The Overwatch game was played with Alienware computers (Aurora R5 D23M;  
2 Dell Inc., Round Rock, TX), mouse (AW558; Dell Inc., Round Rock, TX), keyboard (AW768;  
3 Dell Inc., Round Rock, TX), and monitor (AW2518H; Dell Inc., Round Rock, TX). The monitor,  
4 desk, and chair heights were standardized (0.16m, 0.74m, and 0.44m, respectively), and the  
5 monitor was 0.35m from the front edge of the desk. All subjects fit into the chairs for optimal  
6 comfort and movement distances for game play. The mouse and keyboard positions were adjusted  
7 to each subject's preferred location. Multiple large screens were set up in the room for audiences  
8 to view the various games being played on the monitors of the teams (**Figure 1**).

9 *Figure 1 about here*

10 Subjects wore a Polar H10 chest strap (Polar Electro Inc., Lake Success, NY) to monitor heart rate  
11 throughout the game. The heart rate monitor was paired with the *Polar Beat* app on a tablet  
12 computer to record continuous heart rate throughout the game. The recording was started manually  
13 on the tablet computer when the game began and stopped as soon as the game ended, providing an  
14 accurate game play window for analysis. Again, game play duration ranged from 16 to 25 minutes.

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16 Salivary samples for assessment of cortisol and testosterone were obtained before and after  
17 the game using procedures outlined by Salimetrics LLC (State College, PA, USA). It is well  
18 known that samples that are collected from the salivary biocompartment measure only  
19 concentrations of the "free" or unbound cortisol or testosterone hormone. Briefly, saliva was  
20 collected using unstimulated passive drool. Subjects tilted the head forward, allowing the saliva  
21 to pool on the floor of the mouth, then passed the saliva into a polypropylene vial. Saliva samples  
22 were stored at -80° C until assayed. Samples were assayed in duplicate using ELISA  
23 immunoassays (Salimetrics LLC, State College, PA, USA). The intra-assay variances for cortisol



1 was  $6.2 \pm 1.2\%$  and  $5.1 \pm 1.7\%$  for testosterone with the sensitivities for cortisol and testosterone  
2  $0.018 \mu\text{g} \cdot \text{dL}^{-1}$  and  $1.0 \text{pg} \cdot \text{mL}^{-1}$ , respectively.

3

#### 4 **Statistical Analyses**

5 Data were analyzed using SPSS v.27 (IBM Corp., NY, USA). Normality of distribution  
6 was assessed using the Shapiro-Wilk test. Comparisons for hormonal variables were evaluated for  
7 the whole group of subjects and then classified as low and high skill players. Differences between  
8 groups (based on skill levels before the game play) were assessed using independent T-test and  
9 Independent-samples Mann-Whitney U tests when necessary. Dependent variables between PRE  
10 and POST were assessed for change using two-way (skill levels x time) repeated measures analysis  
11 of variance (ANOVA), with time effects testing the response in these outcomes following the first-  
12 round game, and interactions assessed to determine if these responses are moderated by skill level  
13 in highly involved recreational gamers. To analyze a between-group difference in heart rate  
14 variables, independent T-tests were used. Data not normally distributed were log transformed for  
15 analysis. In the event of a significant F test, pairwise comparisons were further evaluated using  
16 Bonferroni post-hoc procedure for multiple comparisons. Using the nQuery Advisor software  
17 (Statistical Solutions, Saugus, MA), it was determined that the n-size was adequate to defend the  
18 0.05 alpha level of significance with a Cohen probability level of at least 0.80 for each dependent  
19 variable. Statistical significance for all analyses was set *a priori* at  $p \leq 0.05$ .

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## 1 RESULTS

2 Changes in salivary measures of unbound cortisol and testosterone from PRE to POST  
 3 initial game of the competition are presented in **Table 1**. Overall, participants (n= 32) exhibited  
 4 an 11.3% decrease in salivary cortisol and a 17.2% increase in salivary testosterone following the  
 5 game play. Salivary cortisol was not statistically different between skill level groups before the  
 6 game play (P= 0.489). A time x group interaction (P= 0.199) or time effect (P= 0.789) were not  
 7 observed in salivary cortisol, with both high and low skill groups presenting no significant changes  
 8 after the game play. Overall and individual responses of cortisol to the competitive Overwatch  
 9 game is shown in **Figure 2**.

**Table 1.** Salivary cortisol and testosterone measures before and after the game play.

Variables	n	PRE	POST	F- and P-value	
				Skill level x Time	Time
Salivary cortisol, nmol·L <sup>-1</sup> <sup>a</sup>					
<i>All subjects</i>	32	15.9 ± 11.4	14.1 ± 8.1		
<i>Low skill</i>	22	15.0 ± 11.4	14.4 ± 8.9	F= 1.7, P= 0.199	F= 0.1, P= 0.789
<i>High skill</i>	10	18.0 ± 11.7	13.4 ± 6.6		
Salivary testosterone, pmol·L <sup>-1</sup>					
<i>All subjects</i>	32	472.8 ± 191.3	554.0 ± 167.8 <sup>b</sup>		
<i>Low skill</i>	22	418.3 ± 89.5	527.6 ± 132.4 <sup>b</sup>	F= 6.2, P= 0.019	F= 12.6, P<0.001
<i>High skill</i>	10	592.8 ± 290.1	612.1 ± 225.1		

Values are presented as mean ± SD.

<sup>a</sup>, Statistical analysis based on log transformed data; <sup>b</sup>, within-group significant difference

between pre and post values.

Table 1 and Figure 2 about here

1 Overall and individual responses in the salivary testosterone to the competitive *Overwatch*  
2 game is shown in **Figure 3**. There were no differences between the high and low skills groups in  
3 salivary testosterone before the game play ( $P= 0.093$ ). A significant time x group interaction was  
4 observed ( $P= 0.019$ ). Low skill players showed a significant mean increase following the game  
5 play ( $P<0.001$ ), whereas high skill players showed no significant change over time ( $P= 0.634$ ).  
6 Almost all low skill gamers exhibited an increase in testosterone over time, while there was more  
7 variability in response patterns among the high skill group of individuals (**Figure 3**).

8 *Figure 3 about here*

9  
10 Heart rate characteristics during the game play are presented in **Table 2**. The P value noted  
11 is related to the lack of significant differences between skill groups therefore results are presented  
12 as the entire cohort. The average heart rate and maximum heart rate was significantly higher than  
13 the pre-game minimum heart rate in the group with game play.

**Table 2.** Heart rate characteristics during the game play.

Variables	n	Mean $\pm$ SD	P-value
Minimum heart rate, bpm			
<i>All participants</i>	32	81.2 $\pm$ 13.5	
<i>Low skill</i>	22	82.7 $\pm$ 13.5	0.357
<i>High skill</i>	10	87.5 $\pm$ 13.6	
Maximum heart rate, bpm			
<i>All participants</i>	32	133.3 $\pm$ 19.1*	
<i>Low skill</i>	22	131.7 $\pm$ 21.3*	0.491
<i>High skill</i>	10	136.8 $\pm$ 13.3*	
Average heart rate, bpm			
<i>All participants</i>	32	107.2 $\pm$ 17.8*	
<i>Low skill</i>	22	105.8 $\pm$ 18.8*	0.534
<i>High skill</i>	10	110.1 $\pm$ 15.7*	

\* Indicates  $P < 0.05$  compared to minimum heart rate. P-value listed is for statistical comparison of heart rate change between skill groups.

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*Table 2 about here***DISCUSSION**

4 Our understanding of the physiological responses to *Overwatch* game play including in  
5 collegiate recreational yet competitive gamers is non-existent. Is the arousal/stress response similar  
6 to what has been observed in the literature for elite and novice gamers playing other eSport games?  
7 Furthermore, is there a difference due to skill levels which are more highly variable in this group  
8 of collegiate players? These are some of the first questions we endeavored to address for the first  
9 time in this study.

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In this study no significant changes were observed in salivary cortisol despite an 11% decrease with game play. This decrease in cortisol appears to be reflected in the significant statistical impact on a time effect for salivary cortisol. Yet no changes were observed between skill groups. This variable response pattern is reflected in the prior work on other eSport games for salivary cortisol (8, 17, 19). Again, to our knowledge no other study has examined arousal/stress responses to the eSport game *Overwatch* albeit other eSport Games have similar combative/strategy dynamics. As a group there was no significant decline. The overall group findings are in agreement with a study by Gray et al. (8) in which no changes in salivary hormone levels in collegiate recreational eSport gamers were found during *League of Legends* game play. Once game play proceeds it is apparent that optimal brain activity supported by arousal and anxiety levels pre-game may play important roles. The frontal lobe of the brain is highly involved with the processing of attention and executive functions and arousal levels appear to facilitate such functions to a certain extent (1). Mendoza et al. (17) examined a group of expert eSport gamers who participated in tournaments and a recreational control group of gamers who never played eSport games with real strategy demands. It might be suggested that higher skilled players partitioned in this study and in the study by Mendoza et al. (17) would have greater perception of the oncoming game demands. This would lead to greater arousal and anxiety preparing players for more rapid neurophysiological adjustments before game play. Interestingly, Schmidt et al. (19) found increases in salivary cortisol for all players with winners having greater anxiety levels, leading to the concept that higher levels of anxiety may also be favorable for optimizing game performance. Thus, the skill levels of our subjects may not have been high enough in either group to produce any anxiety leading to an adapted pre-game arousal preparation for the competition.

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Cortisol responds to stress and alters functional circuits to limit dysregulation. Expert or more highly skilled players may have both peripheral and central brain neural pathways which allow for facilitation of cognitive and stress modulation compared to lower skilled or novice gamers who have not experienced eSport game demands (10-12, 15, 20). Collegiate gamers may require much more practice and competitive play to mimic cortisol responses similar to highly skilled elite gamers. Thus, salivary cortisol responses to eSport games may be related to the level of game play, experience, and skill levels with competition.

In this study as a group, we observed a significant increase in salivary testosterone pre- to post-game play. Yet interestingly, the high skill group showed significantly higher salivary testosterone concentrations before game play with no changes over time. Lower skilled gamers showed significant increases in salivary concentration of testosterone with game play with no changes in higher skilled players who may have already increased to a pre-game arousal state. However, variability was observed in the high skill group. We know that testosterone plays vital physiological roles in men including competitive venues for winning and losing (5, 12). Testosterone's role in physiological arousal may be related to success in sports due to the need for psychological aggression and physiological adjustments for the so called fight part of the "fight-flight" phenomenon (3-5, 16, 28). Duration of game play was also brought into question for such hormonal responses when a meta-analysis of eSport game competitions suggested that the lack of changes in salivary testosterone may in fact be due to the length of game play with longer games play needed to see increases compared to shorter game play (6). In the study by Gray et al. (8) an acute short gameplay of *League of Legends* (i.e., 15-27 minutes) did not find any changes in

1 salivary testosterone or cortisol and thus game length was used to explain the lack of responses.  
2 Our study provides somewhat novel data on this question that shorter duration game play does  
3 impact hormonal responses. However, the finding that high skilled players may up-regulate  
4 testosterone concentrations prior to game play resulting in no changes with the game play itself  
5 may explain the lack of pre to post game significant effects. Owing to the game context of audience  
6 presence, it may be that the lower skilled players were more affected, as observed audience effects  
7 have been shown to affect testosterone's responses (14). Thus, acute short term eSport *Overwatch*  
8 game play may in fact lead to greater arousal levels of testosterone in more highly skilled gamers  
9 before game play but with game play increases are stimulated in less skilled players.

10

11         It has been known for some time that video game play will elevate cardiovascular demands  
12 during a game (9). Arousal, visual stimuli, emotional responses and game play naturally produce  
13 a sympathetic drive for elevation in heart rate above resting levels (18). In the present study, we  
14 found highly variable heart rate responses in gamers of all skill levels. We report that the heart rate  
15 was maintained throughout the game at about 54% of the age predicted maximal heart rate and it  
16 was variable throughout the game with most heart rates during the game ranging from about 40-  
17 70% of age predicted maximal heart rate range. Yeo et al. (26) also demonstrated moderate  
18 increases in heart rate with game play. With sympathetic drive related to game play and/or  
19 anticipatory stress, elevated heart rate with eSport games is typical for games of all durations (24).  
20 Sousa et al. (23) also showed peak heart rate changes, however, first-person shooter games elicited  
21 a larger change than did multiplayer online battle arena games. This may explain our general  
22 findings for acute cardiovascular stress due to *Overwatch* multi-player team game play regardless  
23 of skill level.

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## **PRACTICAL APPLICATIONS**

At first glance, the passive nature of eSport gaming may indicate little or no physiological stress. However, it is clear from this study that even collegiate gamers experience elevation in heart rate and changes in hypo-pituitary-gonadal functions when playing *Overwatch* in a competitive format. The highly variable response patterns observed for cortisol suggest that changes in sympathetic response may continue as experience with competitive game play increases. Furthermore, skill level may impact the arousal levels of testosterone including adjustments with game play in lower skilled players. Understanding the physiological responses to competitive gaming is the first step in understanding how best to prepare the eSport athlete for competition. The importance of physical conditioning for eSport performance has yet to be determined but it is possible that strength and conditioning programs may help counter the negative health effects of sedentary behavior and enhance the glandular adaptations needed to respond to the physiological stress of eSport competition (21, 22, 27).

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### References

1. Aliyari H, Sahraei H, Erfani M, et al. Changes in cognitive functions following violent and football video games in young male volunteers by studying brain waves. *Basic Clin Neurosci* 11: 279-288, 2020.
2. Bieler D. Ioc announces inaugural slate of olympic licensed esports events. The Washington Post 2021.
3. Carre JM, Campbell JA, Lozoya E, Goetz SM, Welker KM. Changes in testosterone mediate the effect of winning on subsequent aggressive behaviour. *Psychoneuroendocrinology* 38: 2034-2041, 2013.
4. Doan BK, Newton RU, Kraemer WJ, Kwon YH, Scheet TP. Salivary cortisol, testosterone, and t/c ratio responses during a 36-hole golf competition. *Int J Sports Med* 28: 470-479, 2007.
5. Fry AC, Schilling BK, Fleck SJ, Kraemer WJ. Relationships between competitive wrestling success and neuroendocrine responses. *J Strength Cond Res* 25: 40-45, 2011.
6. Geniole SN, Bird BM, Ruddick EL, Carre JM. Effects of competition outcome on testosterone concentrations in humans: An updated meta-analysis. *Horm Behav* 92: 37-50, 2017.
7. Giwa-Osagie SBarker S. Esports & games streaming: Emerging opportunities & market forecasts 2021-2025. 2021.

- 1 8. Gray PB, Vuong J, Zava DT, Mchale TS. Testing men's hormone response to playing  
2 league of legends: No changes in testosterone, cortisol, dhea or androstenedione but  
3 decreases in aldosterone. *Computers in Human Behavior* 83: 230-234, 2018.
- 4 9. Gwinup G, Haw T, Elias A. Cardiovascular changes in video-game players. Cause for  
5 concern? *Postgrad Med* 74: 245-248, 1983.
- 6 10. Joels M, Karst H, Sarabdjitsingh RA. The stressed brain of humans and rodents. *Acta*  
7 *Physiol (Oxf)* 223: e13066, 2018.
- 8 11. Kaldewaij R, Koch SBJ, Zhang W, et al. Frontal control over automatic emotional action  
9 tendencies predicts acute stress responsivity. *Biol Psychiatry Cogn Neurosci*  
10 *Neuroimaging* 4: 975-983, 2019.
- 11 12. Kraemer WJ, Ratamess NA, Hymer WC, Nindl BC, Fragala MS. Growth hormone(s),  
12 testosterone, insulin-like growth factors, and cortisol: Roles and integration for cellular  
13 development and growth with exercise. *Front Endocrinol (Lausanne)* 11: 33, 2020.
- 14 13. Leis OLautenbach F. Psychological and physiological stress in non-competitive and  
15 competitive esports settings: A systematic review. *Psychol Sport Exerc* 51, 2020.
- 16 14. Li Y, Metereau E, Obeso I, et al. Endogenous testosterone is associated with increased  
17 striatal response to audience effects during prosocial choices. *Psychoneuroendocrinology*  
18 122: 104872, 2020.
- 19 15. Lin L, Wu J, Yuan Y, Sun X, Zhang L. Working memory predicts hypothalamus-  
20 pituitary-adrenal axis response to psychosocial stress in males. *Front Psychiatry* 11: 142,  
21 2020.
- 22 16. Maya J, Marquez P, Penailillo L, et al. Salivary biomarker responses to two final matches  
23 in women's professional football. *J Sports Sci Med* 15: 365-371, 2016.
- 24 17. Mendoza G, Clemente-Suarez VJ, Alvero-Cruz JR, et al. The role of experience,  
25 perceived match importance, and anxiety on cortisol response in an official esports  
26 competition. *Int J Environ Res Public Health* 18, 2021.
- 27 18. Porter AMGoolkasian P. Video games and stress: How stress appraisals and game  
28 content affect cardiovascular and emotion outcomes. *Front Psychol* 10: 967, 2019.
- 29 19. Schmidt SCE, Gnam JP, Kopf M, Rathgeber T, Woll A. The influence of cortisol, flow,  
30 and anxiety on performance in e-sports: A field study. *Biomed Res Int* 2020: 9651245,  
31 2020.
- 32 20. Serpell BG, Waddington G, Mcgrath B, Cook CJ. Is there a link between stress and  
33 cognition, and capacity to execute motor skill? *Med Sci Sports Exerc* 52: 2365-2372,  
34 2020.
- 35 21. Siervo M, Gan J, Fewtrell MS, Cortina-Borja M, Wells JCK. Acute effects of video-game  
36 playing versus television viewing on stress markers and food intake in overweight and  
37 obese young men: A randomised controlled trial. *Appetite* 120: 100-108, 2018.
- 38 22. Siervo M, Sabatini S, Fewtrell MS, Wells JC. Acute effects of violent video-game  
39 playing on blood pressure and appetite perception in normal-weight young men: A  
40 randomized controlled trial. *Eur J Clin Nutr* 67: 1322-1324, 2013.
- 41 23. Sousa A, Ahmad SL, Hassan T, et al. Physiological and cognitive functions following a  
42 discrete session of competitive esports gaming. *Front Psychol* 11: 1030, 2020.
- 43 24. Valladao SP, Middleton J, Andre TL. Esport: Fortnite acutely increases heart rate of  
44 young men. *Int J Exerc Sci* 13: 1217-1227, 2020.
- 45 25. Venkat R. Asian games 2022: Esports to make debut; fifa, pubg, dota 2 among eight  
46 medal events. 2021.

- 1 26. Yeo M, Lim S, Yoon G. Analysis of biosignals during immersion in computer games. *J*  
2 *Med Syst* 42: 1-9, 2018.
- 3 27. Yin K, Zi Y, Zhuang W, et al. Linking esports to health risks and benefits: Current  
4 knowledge and future research needs. *J Sport Health Sci* 9: 485-488, 2020.
- 5 28. Ziemba A, Adamczyk JG, Barczak A, et al. Changes in the hormonal profile of athletes  
6 following a combat sports performance. *Biomed Res Int* 2020: 9684792, 2020.

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1 **Figure Legends**

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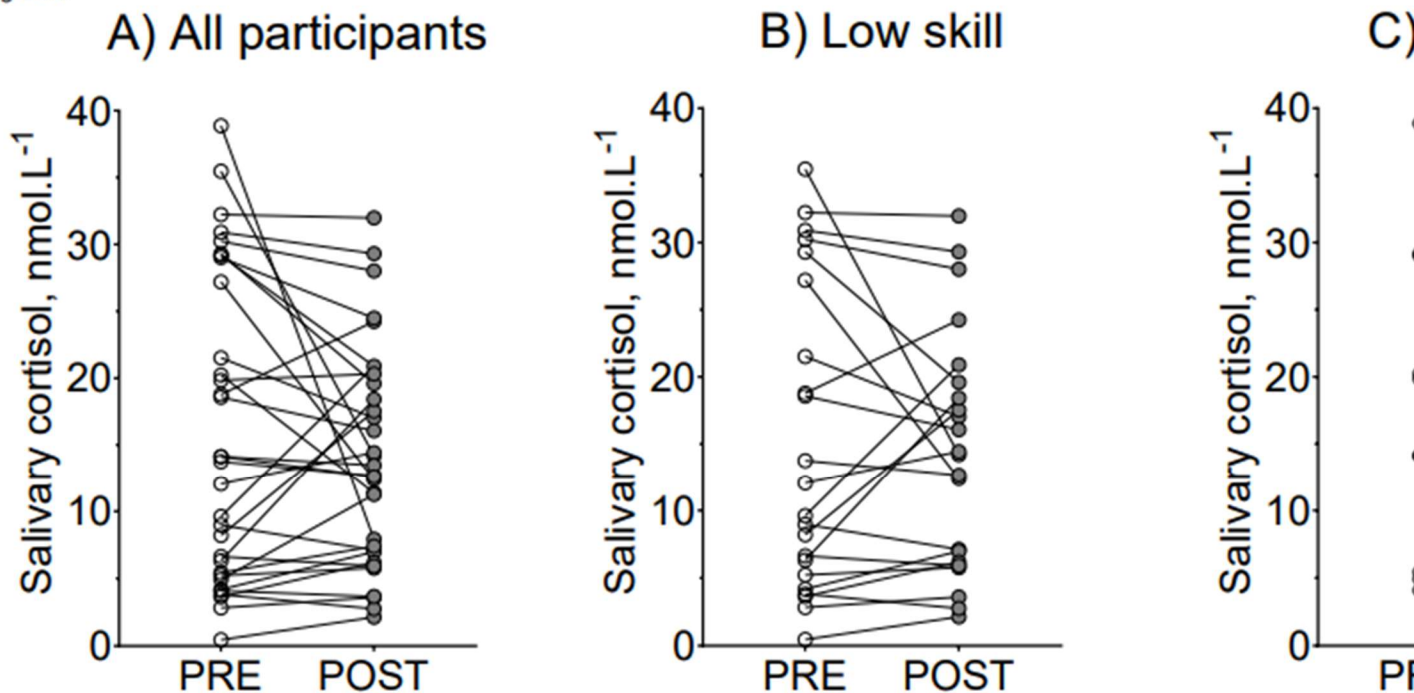
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9 **Figure 1.** Overwatch game play was done in teams of six players in the same large room with  
 10 audiences watching on the competition screens.

Figure 2



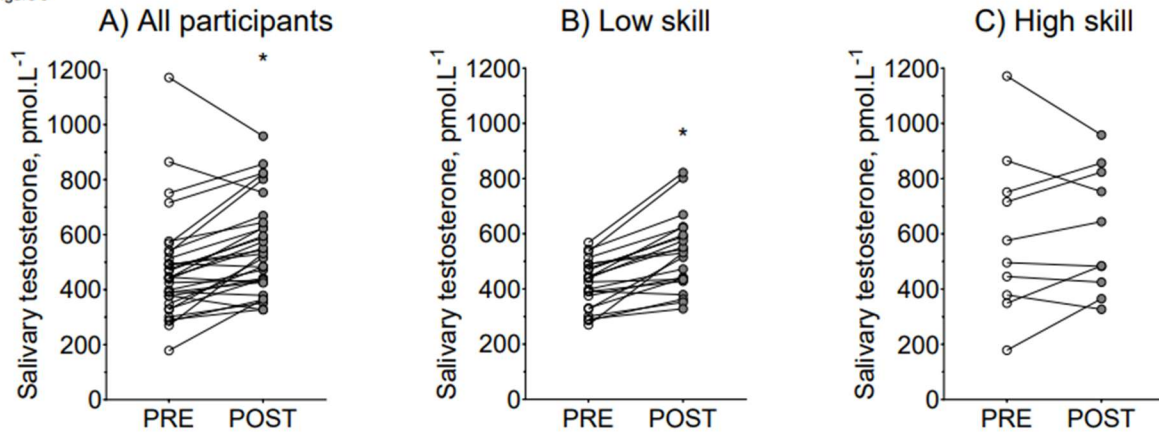
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12 **Figure 2.** Panel A. Individual responses in salivary cortisol for all players to pre- to post-game

13 play. Panel B. Individual responses of each player in the low skill group. Panel C. Individual

14 responses for each player in the high skill group.

Figure 3



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2 **Figure 3.** Panel A. Individual responses in salivary testosterone for all players to pre- to post-game  
 3 play. Panel B. Individual responses of each player in the low skill group. Panel C. Individual  
 4 responses for each player in the high skill group. \* = ( $P \leq 0.05$ ) for significant increases observed  
 5 for the post-game with mean data shown in Table 1.

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