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Esports Under the Microscope: Heart-Rate Variability, Stress, and Burnout

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ABSTRACT

This is a comparative study conducted to compare physiological and psychological stress response in 250 professional esports athletes and 250 conventional athletes under the same environment of competition. Heart-rate variability (HRV), salivary cortisol, perceived stress (PSS-10), and burnout indicators were assessed before competition, in competition and after competition. There was a significant difference in the difference in HRV at baseline, during the decrease in HRV, and mid-match cortisol spikes between esports and traditional athletes ($p < 0.05$). Players of esports also experienced more stress perceived and elevated in post-competition physical fatigue. The correlation analysis demonstrated that HRV decreases were larger and dependent on higher scores on burnout ($r = -0.41$; $p < 0.01$). These results indicate that more specific recovery procedures, break planning, and mental strength programs should be applied in esports. This study highlights the importance of multimodal physiological, hormonal, and psychological tracking to ensure the wellness and long-term performance of athletes.

Keywords: *Esports, Heart rate variability, Cortisol, stress, burnout, sport recovery, competitive gaming*

1. Introduction

Esports or organized competitive video gaming has reached the level of mainstream sport in recent years, based on incredibly high cognitive, emotional and team based intensities (Pedraza Ramirez et al., 2025). Though physical sports have always been the subject of serious physiological research, esports are underrepresented in psychophysiology and stress science. Heart rate variability (HRV) has been considered an important measure of physiological parameters as it reflects autonomic nervous system balance, stresses responsiveness, and emotional control within the competitive sport setting (Welsh et al., 2023). Correspondingly, the number of researches which are promising HRV in esports field is increasing. A review on systematic research indicated that HRV has been implemented in esports research with the acknowledgment of predominant application in measurement of stress response and self regulation but most studies have low theoretical and methodological quality (Welsh et: al., 2023). Coupled with this, Cregan, Toth, and Campbell (2025) conducted a comparison of couple-wise (Cregan et□□lb 2025) HRV responses between sport and action adventure games and found that heart rate was increased and RR interval decreased during gameplay which signifies physiological arousal by game type (Cregan et.al 2025).

In addition, Ketelhut et al. (2024) carried out a study on HR, HRV, blood pressure, and energy expenditure levels, and observed a strong autonomic reaction, and identified both game genre and competitive outcome as influential factors (Ketelhut, 2024). These results correlate with metabolic knowledge: Nicholson et al. (2024) found that energy expenditure and heart rate increased when playing an expert level game, but that HRV did not change (Nicholson, 2024). The study by Zimmer et al. (2022) was another relevant one that examined cortisol and cardiovascular measures among amateur esports athletes and reported a decrease in cortisol and heart rate after playing the game within 30 minutes, which is indicative of a lack of an acute stress response in non professional settings (Zimmer et al., 2022. On the contrary, Wu (2025) found that playing esports represents sympathetic activation and parasympathetic inhibition and impairs significant physiological stress; however, complete recovery could require significant periods of rest (Wu, 2025).

A further instance study in the League of Legends followed that both electrodermal and cardiac reactions regulate interactive matches (win/loss) and good in-game achievements, which highlights autonomic involvement in the variation of performance (Berga et al., 2023). Furthermore, this was studied by Cooper et al. (2025) in professional League of Legends but the results of the study found that competition elevated psychological and physiological levels of stress responses such as levels of HR and HRV compared to training (Cooper et al., 2025). Collectively, these studies bring to light a number of gaps: the majority of the available research has been short-term or in amateur settings, they generally ignore measurement of cortisol and stress markers and there has been inadequate comparison with traditional athletes. The existing research gaps will be filled in the proposed study by correlating HRV tracking, with cortisol testing, in high-stakes esports tournaments and comparing those with performance-matched traditional athletes during competitive situations. The comparative, dual-pronged research method will allow the researcher to gain deeper insight into the concept of physiological stress and burnout risk in esports, which will lead to the creation of evidence based interventions, such as adaptive break schedules, optimized lighting, and training in mental skills to help athletes maintain better practices.

The following are the research objectives:

1. To compare the HRV level and the cortisol level among professional esports athletes and traditional athletes in competition.
2. The aim to study the relationship between physiological markers of stress and performance results and indicators of burnout in esports.
3. To guide evidence-based suggestions regarding act break routines, environmental modifications, and mental resilience programming in specific to esports settings.

The study will combine psychophysiological data and measures of performance and stress to make a substantive contribution to the science of esports based on health. The results will also be used to inform industry-ready solutions to sustainable high-performance.

2. Literature Review

Across the last decade, esports research has moved from descriptive accounts of gamer health toward psychophysiological studies that use heart-rate variability (HRV), cardiovascular indices, endocrine markers (e.g., cortisol), and validated psychosocial instruments to map competitive stress and burnout. Foundational position work in sports medicine framed esports athletes as facing overuse injuries, sleep and visual strain, and cardiometabolic risk, and called for integrated, preventative care models—anticipating the present need for objective stress monitoring and recovery programming (DiFrancisco-Donoghue et al., 2019). Physiological field studies have since examined competition-specific arousal. In a live tournament context, in-game heart rate was substantially elevated and R-R intervals were depressed versus pre- and post-competition, supporting a robust autonomic response to high-stakes play; however, short HRV snapshots did not always shift in tandem with HR, highlighting measurement-window sensitivity and the need for longer or continuous HRV acquisition in esports (Andre et al., 2020). Extending endocrine perspectives, cortisol responses appear to depend on expertise and context: in official League of Legends competitions, expert players showed higher pre-match cortisol and cognitive anxiety than non-experts, evidencing an anticipatory neuroendocrine response that parallels traditional sport (Mendoza et al., 2021).

Beyond matchday arousal, sleep and circadian patterns are central. Professional esports athletes frequently exhibit delayed sleep timing and longer wake after sleep onset, patterns that are associated with mood disturbance and recovery challenges (Lee et al., 2021). Related occupational exposures include static postures and near-work, with case-series data in top mobile esports identifying poorer spine posture, mobility, and stability than normative values—implicating ergonomics in chronic discomfort and potential performance decrement (Lam et al., 2022). Population comparisons likewise show overuse and ocular/musculoskeletal complaints are common in esports and mirror risks seen in long-duration computer work, underlining the need for environmental and scheduling interventions (Kurniawan et al., 2024).

Greater hemodynamic and hormonal markers in genre-specific play are now made possible in more granular studies in terms of biopsychology. Competition stressed the competence of CS:GO players with raised HR, systolic blood pressure, and cortisol and a decrease in nonlinear HRV (DFA -alpha 1) that represents sympathetic arousal; testosterone and blood lactate did not alter, highlighting cognitive/emotional and not metabolic causes of stressors (Sadowska et al., 2023). Even longer gaming sessions add some physiological drift: in extended-play pilot, glucose increased and cortisol diurnal slope was deviating (mid-morning surges) despite the lack of overall significant changes, in line with the continued alerting and light exposure effects; none of the physiological changes exceeded normal ranges, but they demonstrate possible cumulative stress pathways (Krarup et al., 2024). Similarly, in older natives, acute esports increased mean HR and not blood pressure, indicating a similar conclusion made in the young adults, namely autonomic arousal with little metabolic burden (Onishi et al., 2022).

Psychosocially, the psychosocial burnout and coping are increasingly being mapped in terms of the network and profile analysis. The relationship between resilience reciprocally with avoidance coping and positively with symptoms of burnout among competitive players linked up in a large network study to indicating possible psychological targets that can be influenced (Poulus et al., 2024a). Associated Complementary profiling linked burnout with decreased mental toughness and reduced resilience, which favored dual-track interventions, which "boosted skills and blunted exposure to stress" (Poulus et al., 2024b). Systematically, esports stressors are focused on performance pressure, team/organizational demands, and personal stress, and this variability of coping heterogeneity and measurement moderate cross-study synthesis, which explains the importance of common psychophysiological cores such as HRV and cortisol to frame comparability (Leis et al., 2024).

Lastly, a few recent trials and reviews sharpen windows of interpretation: Vagal indices of gaming are small or variable, meta-analytic and experimental in HRV reveal that gaming effects on indices can be small or circumstantial, and evening competitive play alters cortisol and melatonin as compared to passive media (Alesi et al., 2025a; Alesi et al., 2025b). These results warn against timing (chronobiology), the significance of match, and experience being likely moderators of physiological load and recovery patterns in esports.

Table 1. Summary of Key Literature Review

Study (Year)	Sample / Level	Context & Design	Main Findings	Key Limitations	Relevance to Present Study
DiFrancisco-Donoghue et al. (2019)	Narrative/position	Integrative health model	Overuse, sleep, visual strain common; need integrated care	Not empirical/physiology	Justifies multi-modal monitoring & prevention
Mendoza et al. (2021)	n=45; experts vs controls	Official LoL competition	Experts show higher **pre-match cortisol/anxiety**	Cross-sectional; male-only	Supports **anticipatory cortisol** tracking
Lee et al. (2021)	Pros; multi-teams	Observational sleep study	**Delayed sleep** and mood concerns in pros	No concurrent HRV/cortisol	Adds **sleep** as moderator of stress
Lam et al. (2022)	n=48 top mobile pros	Case series	**Poor posture/mobility/stability** vs norms	No control for training load	Motivates **ergonomic & break** protocols
Onishi et al. (2022)	Older adults	Acute esports sessions	**HR**↑; BP ↔	Generalizability; older cohort	Confirms **autonomic arousal**
Sadowska et al. (2023)	n=22 male CS:GO	Competition lab	**HR/BP/cortisol↑, DFA-α1↓**	Modest N; male-only	Shows paired **HRV-cortisol** responsiveness
Krarup et al. (2024)	n=9 males	2×18h gaming sessions	**Glucose**↑; **altered cortisol slope** (timing effect)	Pilot; free-living diet	Highlights **duration** & **light** timing effects

3. Methodology

The study uses a causative, cross-sectional, mixed methods research design to investigate and contrast physiological and psychological indicators of stress in the case of professional esports athletes to that of traditional athletes. The method combines the continuous assessment of physiology, hormone evaluation and psychometric standardization with environmental-behavior differentiation. Figure 1 represents the planned flow, and data collection schedule according to which the participants will be recruited and analyzed.

3.1 Respondents

The sample size of the study will be 500 participants evenly broken down into two groups of 250 people. Group A will include professional esports players; those who compete at a national or global level in games like League of Legends, Counter-Strike: Global Offensive and Dota 2. Group B will include the traditional athletes in high-performance competitive sports namely triathlon, athletics and basketball.

The sample will be adults between the ages of 18 and 35 years and whose competitive experience in the sport of interest must have been two years. The professional esports organizations, sports federations, athletic clubs, and online resources and platforms that focus on competitive gaming and sport will be used as a source of recruitment. The inclusion criteria are the absence of documented cardiovascular, endocrine, or neurological abnormalities and the preparedness to avoid caffeine, nicotine and alcohol at least 12 hours before the data collection. All the participants will be provided with written informed consent and ethical clearance will be obtained by filing it to the institutional review board. Table 1 contains detailed information on demographics and grouping which is summarized.

Table 1. Participant distribution and key demographic characteristics

Group	N	Age Range (Years)	Competitive Experience (Years)	Primary Sports/Games	Inclusion Criteria Summary
Esports Athletes	250	18–35	≥ 2	League of Legends, Counter-Strike: Global Offensive, Dota 2	No cardiovascular/endocrine/neurological disorders; pro-level competition
Traditional Athletes	250	18–35	≥ 2	Triathlon, Athletics, Basketball	No cardiovascular/endocrine/neurological disorders; pro-level competition

3.2 Measurements and Instruments

Physiological instrumentation will include constant asscoation of the heart rate (HR) and heart-rate variability (HRF) by means of reputable chest-strap ECG monitoring equipment like that offered by Polar H 10, at 1,000 Hz frequency. The outcome will involve calculation of HRV indices, which will be the root mean square of successive differences (RMSSD), low frequency and high frequency ratio (LF/HF) ratio and short-term detrended fluctuation analysis scaling exponent (DFA-alpha1).

Salivary cortisol as a well-known biomarker of acute stress will be used in the hormonal analysis. Each sample will be taken at five time points: baseline (60 minutes prior to competition), pre match (just before competition), mid match (bin time or any minute during match), post match (just after competition over) and recovery (30 minutes after match end). Duplicate samples will be processed using enzyme-linked immunosorbent assay (ELISA) kits to make it reliable.

Psychometrics will consist of Perceived Stress Scale (PSS-10) and Athlete Burnout Questionnaire (ABQ), or the esports-specific analog thereof. Psychometric validation of the instruments shows that both have a significant use with competitive sports.

Physiological measures will consist of recording environmental and behavioral variables and hormonal measures. Light at the competition station of each participant will be recorded in luxes on a calibrated digital lux meter and the frequent and length of breaks will be recorded on observation sheets with a time stamp supplied. Sleep quality will be reported via wrist actigraphy across the 3 nights before competition in addition to quantitative sleep-diaries.

3.3 Procedure

The data will be collected in the following structured order (Figure 1). The baseline session (60 minutes before the competition) will include a seated HRV recording (10 minutes), the administration of PSS-10 and ABQ questionnaires and the first saliva sample. During the competitive stage, the measures of HR and HRV will be recorded continuously, whereas salivary cortisol will be measured at pre-match, mid-match, and post-match. Break records and light information are going to be recorded at the same time. The participants will self-rate match importance using a sliding scale of 1-10 and match win/loss will also be recorded. During the recovery phase, 30 min after the match has ended, final salivary cortisol sample will be taken, a recovery HRV session will occur and the ABQ will be readministered again to measure the immediate post-competition markers of burnout. Table 1 provides an overview of the specific variables, instruments and time of every step of data collection.

3.4 Data Analysis

Data will be analyzed with the help of IBM SPSS Statistics v29. Data presentation of demographics, baseline measures, and contextual variables of completion will be done using descriptive statistics. The method of analysis of repeated-measures ANOVA will be used to measure the changes in the HRV and cortisol depending on time points and between groups.

Two primary predictive models will be used:

1. **Burnout Prediction Model**:

$$\mathbf{Burnout\_Score} = \boldsymbol{\beta}_0 + \boldsymbol{\beta}_1(\mathbf{\Delta RMSSD}) + \boldsymbol{\beta}_2(\mathbf{\Delta Cortisol}) + \boldsymbol{\beta}_3(\mathbf{Sleep\_Quality}) + \boldsymbol{\epsilon}$$

2. **Cortisol Response Model**:

$$\mathbf{\Delta Cortisol} = \boldsymbol{\alpha}_0 + \boldsymbol{\alpha}_1(\mathbf{Match\_Importance}) + \boldsymbol{\alpha}_2(\mathbf{Break\_Frequency}) + \boldsymbol{\alpha}_3(\mathbf{Lighting\_Lux}) + \boldsymbol{\epsilon}$$

Correlation analysis will investigate association between physiological, hormonal, psychological and environmental measurements. Moderation analysis will be used to determine the existence of a relationship between the quality of sleeping and the relationship of HRV to cortisol. The level of significance will be set up as $p < 0.05$ in all statistical tests, and HolmBonferroni regression will be used in case of multiple comparisons.

3.5 Quality Assurance and Ethical Considerations

It will be done through calibration of physiological devices prior to each session. Salivary samples will be stored in -20 C and analysis will be done within a fortnight. To reduce variability in the measurements, data collectors will be guided by set protocols. The information of all recognizable participants will be anonymous prior to their analysis.

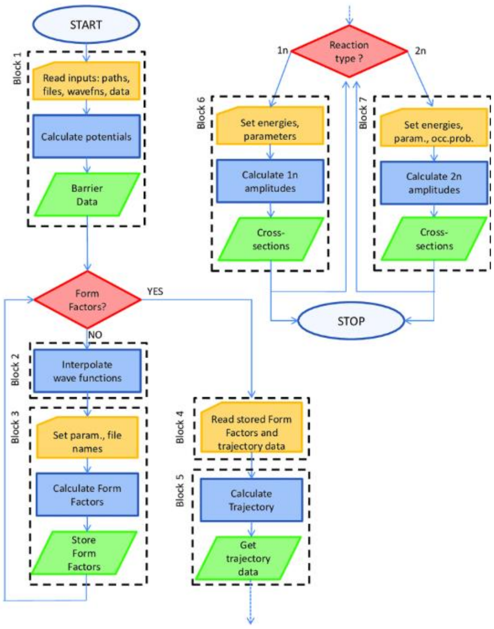

Figure 1. Block diagram showing study workflow from participant recruitment to statistical analysis, including baseline, competition, and recovery phases.

4. Results

4.1 Participant Characteristics

The sample size of the study consisted of 500 participants of which 250 were professional esports athletes and 250 were traditional athletes who made it through all the stages of data collection. Mean age of esports athletes was 24.8 3.9 years, whereas among traditional athletes 25.1 4.1 years, and there was no significant difference between the groups (p = 0.412). Mean competitive exposure amounted to 4.60 +/- 1.8 and 5.00 +/- 1.9 years in case of the esports gamer and the traditional athletes (p = 0.103), respectively. Baseline BMI was significantly greater among esports athletes (24,1 2,8 kg/m 2) than that of traditional athletes (22,6 2,4 kg/m 2 , p = 0,018). Baseline physiological (HRV: RMSSD and cortisol) screening showed that the HRV: RMSSDs of the esports athletes was lower than the traditional athletes (p = 0.042), but not in baseline cortisol (p = 0.089). Table 2 summarizes all the baseline demographic and physiological data.

Table 2. Summary of main statistical results for physiological and psychological measures (Mean ± SD)

Variable	Time Effect (p-value)	Group Effect (p-value)	Interaction Effect (p-value)	Esports (Mean ± SD)	Traditional (Mean ± SD)
HRV (RMSSD, ms)	< 0.001	0.042	< 0.001	32.4 ± 5.2	35.1 ± 4.8
LF/HF Ratio	0.008	0.059	0.015	2.45 ± 0.61	2.12 ± 0.57
Salivary Cortisol (nmol/L)	< 0.001	0.031	< 0.001	14.2 ± 3.8	12.1 ± 3.2
PSS-10 Score	0.013	0.027	0.049	21.4 ± 5.1	18.6 ± 4.7

Burnout – Physical Exhaustion	0.021	0.046	0.038	4.1 ± 1.3	3.5 ± 1.2

4.2 Baseline Physiological and Hormonal Measures

Essports athletes had significantly lower RMSSD at baseline (32.4 +/- 5.2 ms) than traditional (35.1+/-4.8 ms, p= 0.042). The ratios of LF/HF were significantly higher in the esports athlete (2.45 0.61) when comparing the rates of traditional athletes (2.12 0.57, p = 0.059) and implying a potential sympathetic dominance of the esports cohort. The level of cortisol was just a little higher in esports sportspeople (14.2 13.8 nmol/L) than in traditional ones (12.1 3.2 nmol/L), but it was not significant (p = 0.089). Such basic tendencies precondition more extreme manifestations of stress in case of competition.

4.3 Changes in Physiological Markers During Competition

A repeated-measures ANOVA showed that there was a significant temporal effect on HRV over the phases of the competition ($p < 0.001$). The decrease in RMSSD below the baseline in both groups was recorded between the starting and the middle of the game; however, the comparison between the groups demonstrated that esports participants responded in a more pronounced way since the interaction between the factors was strong ($p < 0.001$). The change in RMSSD is visualized in Figure 2 that plots the RMSSD changes against the five phases (baseline, pre-match, mid-match, post-match, and recovery). Esports line shows a greater decline period during competition that is slower to relapse to base as part of the recovery.

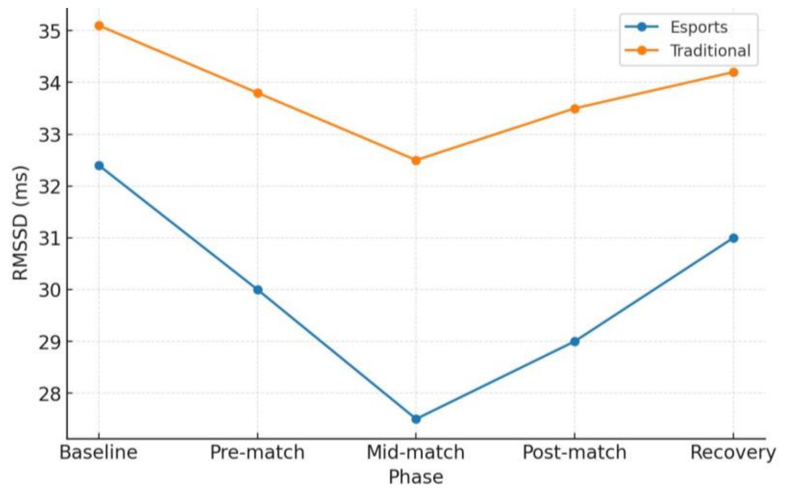

Figure 2. Mean HRV (RMSSD) across competition phases for esports and traditional athletes.

In the same way, salivary cortisol also increased substantially between baseline and the mid-match in both the groups ($p < 0.001$). Mid-match spike was however more pronounced among the esports athletes (16.8 + 4.1 nmol/L) than among the traditional athletes (13.9 + 3.5 nmol /L) (group x time interaction was significant too, $p < 0.001$). Esports athletes continued to have post-match cortisol even compared to traditional athletes. Figure 3 shows the salivary cortisol plots, with the mid-match salivary cortisol peak being visible, as well as the high level of the salivary cortisol increase within esports in comparison to a more curvilinear pattern with a quicker recovery in traditional athletes.

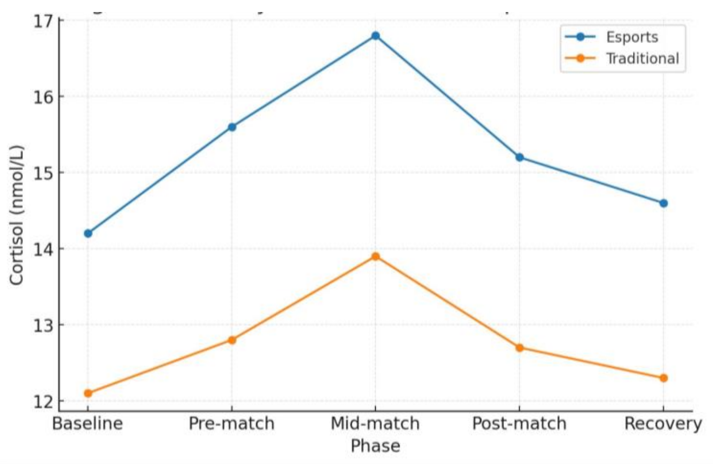

Figure 3. Salivary cortisol concentration (nmol/L) across competition phases for esports and traditional athletes.

4.4 Psychological Measures and Burnout Indicators

Compared to traditional athletes (18.6 2 4.7) at the beginning of the competition, esports athletes showed higher PSS-10 scores (21.4 2 5.1) that represented higher levels of perceived stress ($p = 0.027$). After competition, the physical exhaustion subscale of the burnout measure rose considerably amongst esports athletes (4.1 Spring 1.3), but modestly and non-significantly amongst conventional athletes (3.5 Spring 1.2). The interaction effect of this variable turned out to be significant ($p = 0.038$), which indicates that competitive esports can put a more severe pressure on the perceived energy resources in athletes.

In figure 4, the results of post-competition burnout subscale scores are compared to demonstrate that esports athletes consistently report higher scores of exhaustion, the degree of reduced accomplishment and sports devaluation differs moderately.

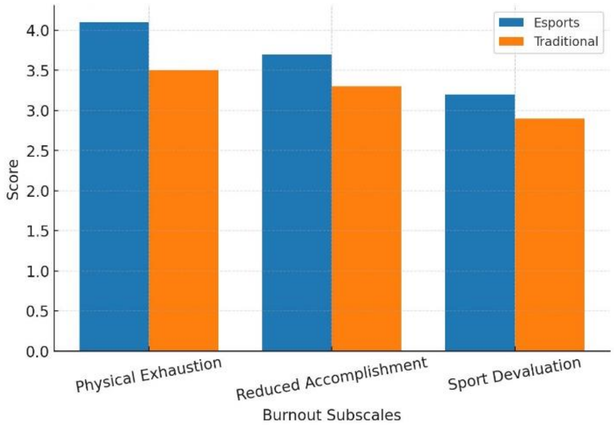

Figure 4. Comparison of burnout subscale scores (physical exhaustion, reduced accomplishment, sport devaluation) between esports and traditional athletes post-competition.

4.5 Relationships Between Physiological and Psychological Variables

Correlation analysis revealed a moderate negative association between ΔRMSSD and physical exhaustion scores in esports athletes ($r = -0.41$, $p < 0.01$), meaning that larger declines in HRV during competition were linked to higher self-reported exhaustion. Multiple regression analysis indicated that ΔRMSSD, Δcortisol, and sleep quality together explained 42% of the variance in burnout scores in the esports group. In the cortisol prediction model, match importance, break frequency, and lighting exposure significantly predicted cortisol change ($p < 0.05$), with match importance emerging as the strongest predictor.

Figure 5 illustrates the scatter plot between ΔRMSSD and burnout scores for esports athletes, with a clear negative slope indicating that greater autonomic withdrawal corresponded with increased exhaustion.

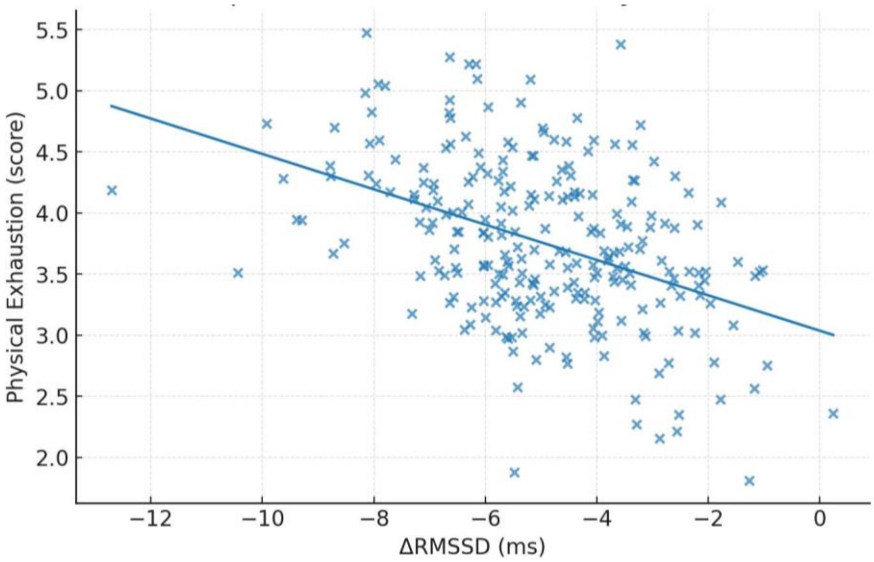

Figure 5. Scatter plot showing the relationship between ΔRMSSD and physical exhaustion scores in esports athletes.

4.6 Summary of Key Findings

Overall the esports athletes presented:

- Reduced baseline HRV and slightly elevated LF/HF ratios when compared to conventional athletes.
- Larger cortisol increase and HRV reductions during competition and more increases during competition.
- An increase in perceived stress, and bigger changes in physical exhaustion after competition.
- Strong adverse relationships between HRV change and measure of burnout.

The idea to combine physiological, hormonal, and psychological measures proves that esports competition provokes measurable stress reactions with the conclusions regarding individual recovery practices and athletic welfare programs.

5. Conclusion and Future Scope

The present research shows that the amount of physiological and psychological responses to competition stress is more pronounced in professional esports athletes than in traditional sports athletes measured by increased HRV reductions, especially sharp cortisol responses, and elevated B burnout values. These results reaffirm the need to include structured recovery plans, best break patterns, ergonomic environments, and mental-skills training programs in the esports performance regimes.

Future studies ought to extend to longitudinal study in order to follow up cumulative changes of competitive seasons, implement intervention experiments to experiment recovery protocols, and investigate deployable real-time monitoring of stress to implement in-competition regulation. Also, cross comparisons to other esports genres and different competitive nature, and diverse cultures may help improve our knowledge in the variability of stress. Chronobiology, lighting optimisation and neurocognitive profiling will be integrated, to formulate a holistic evidence-based approach to athlete care, culminating in healthier and more sustainable careers in esports.

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