International Journal of Esports

Continuous monitoring of HRV in esports players

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Abstract

Aims: Esports is a rapidly growing industry with large global revenue streams which have been used to invest in player performance and offer substantial monetary prizes for competitive players. Heart rate variability (HRV) has been studied widely as a measure of sympathetic activity and stress. Whilst often employed in athletes to monitor condition and performance, it has scarcely been explored in esports.

Methods and results: This study assesses observational changes in time domain variables of HRV over the course of an esports session. We found that mean Standard deviation of RR intervals (SDRR) was lower in the winning team compared to the losing team and that there were certain areas of analogous change in HRV in multiple players, mainly at the end of play. However, our results show that throughout most of the session there was considerable intra-player variability in HRV and that without high resolution contextual information it is not possible to confidently link this data with performance.

Conclusion: Our results add further evidence of HRV being a sensitive measure of stress that requires further study to extract meaningful results.

Highlights:

- There is moderate correlation between esports and heart rate variability, with similar changes seen in players of both teams during the session.

- Overall, heart rate-variability varies considerably making observer interpretation difficult and without recording of gameplay there is a limited ability to contextualise results.
- To interpret and analyse heart rate variability a high-level of study and analysis would be required to produce valuable results.

Keywords:

Esports, Heart rate variability, Cardiology.

Introduction

Esports involves the competitive playing of video games between individuals or teams and has seen a rapid growth in popularity across the world. Viewership is expected to rise from 454 million in 2019 to 646 million in 2023 and the value of the industry is estimated to be as high as $24 billion, with prize-pots for major esports tournaments eclipsing those of established, major sports tournaments (1,2). In response, there has been a considerable increase in investment and analysis of esports professionals to improve performance. However, at present there is a lack of evidence to guide training regimes and much of the current approach is based on academic work done with regards to physical activity, supported by a belief from esports players themselves that such methods can enhance performance (3).

One parameter which has attracted attention regarding physical activity and athletes is heart rate variability (HRV). HRV describes the change in the interval between successive heartbeats, these oscillations reflect the activity of the autonomic nervous system and responses to external stimuli (4). HRV is widely considered to reflect changes in sympathetic and parasympathetic nervous systems and measurement provides insight into their relative activities (5,6).The measurement and evaluation of HRV is split into time domain and frequency domain analysis. Time domain analysis quantifies the amount of variability in the RR interval, the time between contiguous QRS's in sinus rhythm. Common time domain measures includes the standard deviation of RR intervals (SDRR) and root mean square of successive RR interval differences (RMSSD) (5). Frequency domain analysis defines the heart rate signal in frequency bandwidths; primarily as low frequency or high frequency components. Their relative power is quantified to assess the contribution of either the parasympathetic or sympathetic nervous systems to changes in HRV (6). HRV measurement can be performed over varying lengths of time often split into 24 hours (long term), 5 minutes (short term) and less than 5 minutes (ultra-short term) (4,5). Whilst most studies previously focussed on the use of long and short term measurement, the increasing demand for analysis based on mobile devices has led to several studies validating to use of ultra-short term values (7,8).

Many physiological factors can affect HRV such as age, gender, respiration, heart rate, blood pressure and circadian rhythm (9,10). In clinical medicine, a higher HRV has been shown to be associated with improved outcomes with regards to mortality and morbidity, whereas the opposite is true for those with a lower HRV (11–13). Patients who undertake physical activity as either part of a rehabilitation plan or recreationally have been shown to have improved outcomes as well as increased time and frequency values of HRV when compared to less active individuals (14,15). This increase in HRV with physical activity is also seen in healthy individuals and athletes (16,17). Indeed, time domain values of HRV seem to be associated with fitness (18). This reflects an increase in parasympathetic tone that is seen in athletes during physical training, which also produces a bradycardia at rest (19). In sport and physical activity, HRV has been increasingly studied over recent years with a view to develop athletic performance. Training regimes at the elite level often have a high training burden with short periods for recovery. Research around HRV in physical activity has therefore focussed on measuring HRV change during exercise, after exercise and over a prolonged period of training. Higher intensity exercise leads to a greater change in HRV, which subsequently takes longer to return to the resting HRV than if lower intensity exercise was undertaken (20,21).

HRV has also been used to assess mental stress and response to tasks. Whilst driving, HRV is able to differentiate high-demand periods with single task driving, although this is not consistent across time and frequency measures of HRV (22). A meta-analysis of 37 studies found that HRV changed in response to stress and was sensitive to changes in the autonomic nervous system (24).

There is limited understanding on the application of HRV in video games or esports. Observational work suggests significant variation in heart rate and HRV during and after playing a racing simulation video game (25). More recently Andre et al showed HRV variance before, during and after esports activity (26).

HRV measurement may therefore provide a way to tailor training, determine rest periods, prevent over-exercising and provide insight into the emotional response of athletes to competition. (27–30). The advent of wearable devices, such as smart watches, which can measure physiological parameters including HRV has led to an uptake in interest in HRV and its potential application in performance and health.

A greater understanding about how HRV changes throughout an esports session would in theory, allow for recognition of the body's response and autonomic activity during this activity and its relation to performance. This paper will explore how HRV is affected and how useful it is for assessing an autonomic response during an esports session.

Methods

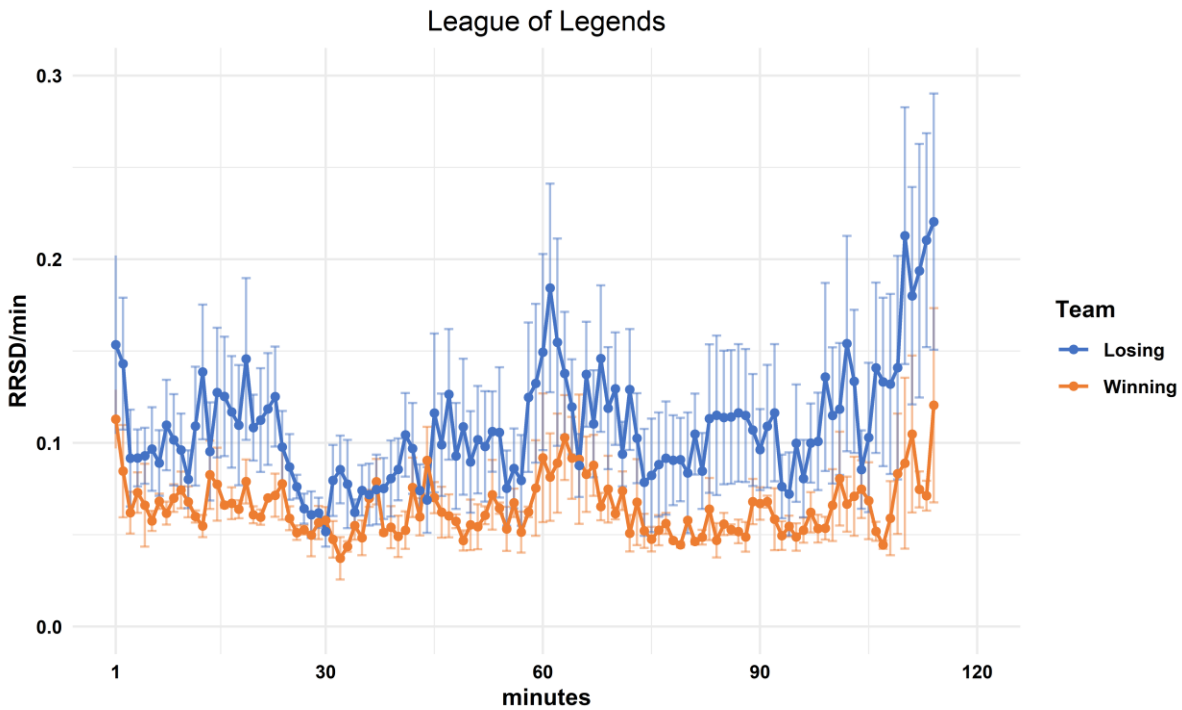
This observational study was approved by the New York Institute of Technology (NYIT) Internal Review Board and was conducted as a well described prospective study by Sousa et al [8]. Participants signed written consent to take part in the study which was located at the NYIT esport arena, Old Westbury, NY, USA. Inclusion criteria included men or women between the ages of 18-30. Exclusion criteria included players who had not played competitively in the last year, were unable to wear the smart shirt or had an injury that would affect their gameplay.

Following informed consent, smart shirts were fitted on the participants after which competitive play started. Participants wore the Hexoskin Smart Shirt® (5800 Denis St. Montreal, Quebec H2S-3L5) which is similar to a standard T-shirt and worn directly on the torso. The smart shirt contains electrodes that measure common physiological parameters including HRV through NN and RR intervals. Participants competing in LoL played in two consistent teams against each other, whilst OW players competed in cooperative teams of 2-4. Physiological parameter recording started upon placing the suit on the participants. After completing the esports session ranging from 1.5 to 2.5 hours across the two cohorts, participants removed the Hexoskin suit for data extraction.

Statistical analysis

Values for the RR and NN intervals were recorded by the Hexoskin Smart Shirt® and used to produce time-domain measures of HRV. Poor quality RR interval values, corrupted by noise in the ECG signal, were removed to improve the quality of data. Furthermore, to enhance the quality of the inference, removed values were interpolated using a standard cubic spline method. SDRR was then calculated for each minute of play for individual players. Players were then grouped into winning and losing teams and a mean value of SDRR was taken for each minute. This was then plotted onto a graph (Figure 1) allowing comparison of SDRR over time for both winning and losing teams.

Figure 1 – Change in HRV of teams over an esports session.



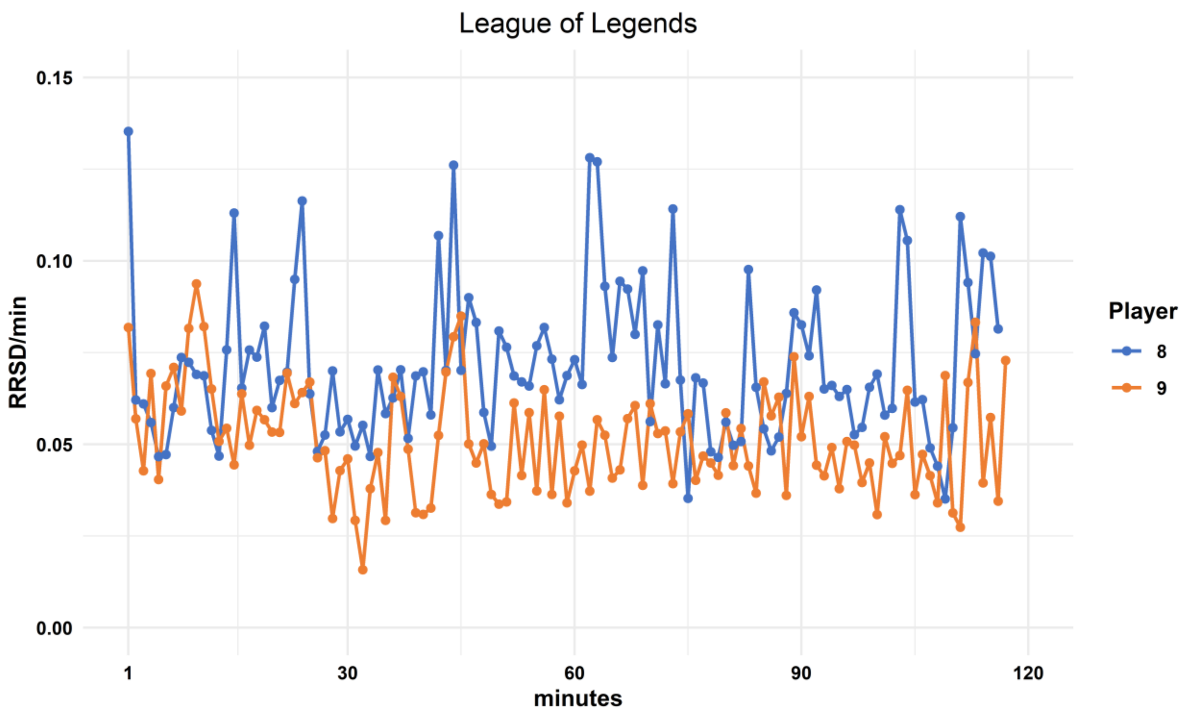
Results

A statistical similarity comparison was performed over pairs of members of the same team. A significance of a statistical similarity between normalized and smoothed signals was based on values of mean squared error (MSE), mean absolute error (MAE), and Pearson's correlation coefficient r. Lower MSE/MAE values indicate greater similarity between signals, while correlation coefficient closer to 1 indicates that the two signals agree with each other.

Tables below summarise the similarity values between players and teams. We make an interesting observation that at the team level the HRV could be treated as a relatively good indicator at distinguishing rest and esports activity periods (Figure 1), while at the player level it is not reliable (Figures 2-3, Tables 1-2). The reason that HRV is performing better at the team resolution, is the phenomenon called "signal averaging" (30). Due to the averaging performance over the members of a team in the time domain, we have increased the strength of a signal relative to the noise that is obscuring it. The more members a team has, a higher signal-to-noise ratio (SNR) becomes, in turn, more clearly revealing global patterns in a signal, such as periods of rest and esports activity. This is reflected in Table 3, where a significant r of 0.78 was observed, revealing an agreement in global patterns between HRV signals of winning and losing teams. On the other hand, at the player level, within a team we can see a rather poor correlation (Table 1) or outright disagreement (Table2).

19 male players took part in the study across the two cohorts (Table 1). The winning team appears to have a generally lower HRV (Figure 1), however, significant variation in HRV was noted between players regardless of team allocation (Figure 2). One instance of similarity in HRV pattern during esports activity was identified in both cohorts (Figure 3).

Figure 2 – Intrateam variability across multiple game titles.



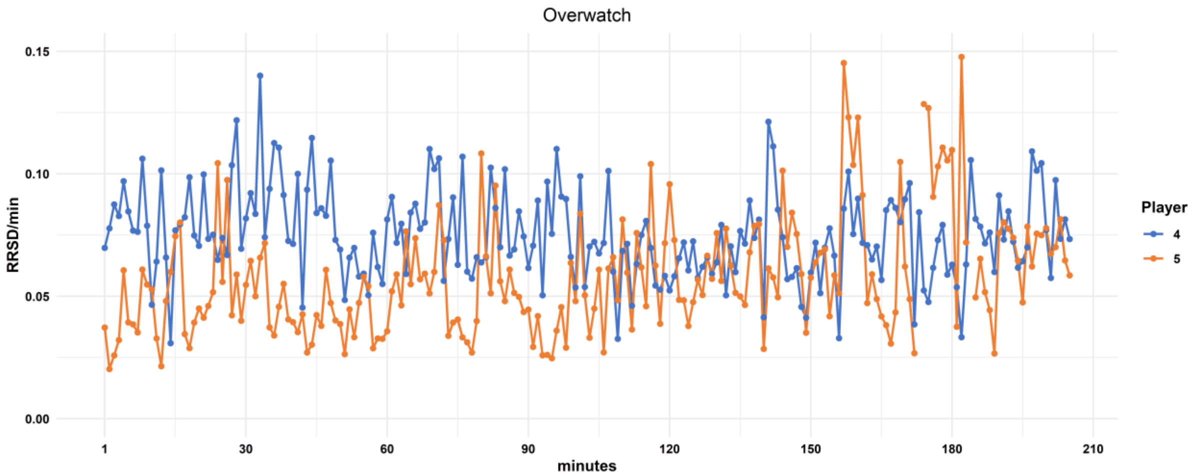
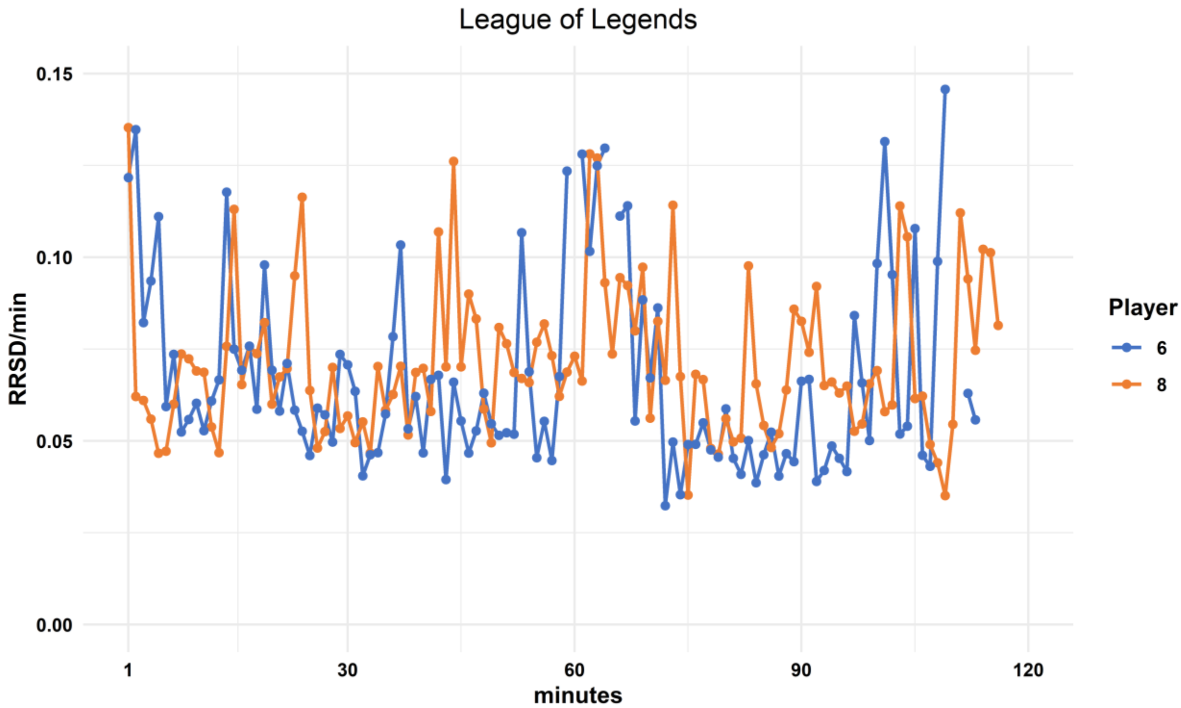


Figure 3 – Similarities in HRV within teams during esports activity.



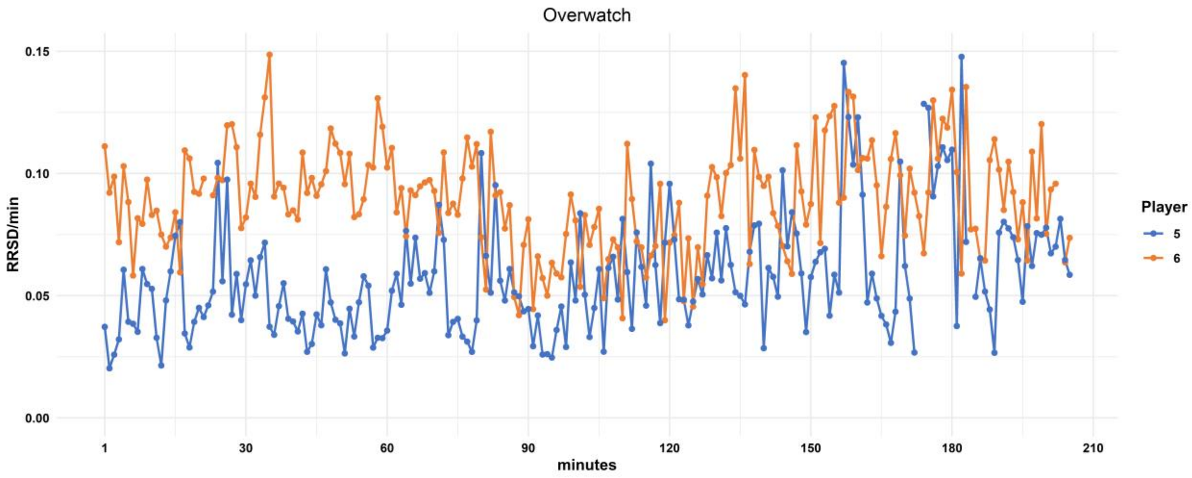


Table 1 – Comparison between selected players in League of Legends (LOL). MSE – Mean standard error, MAE – Mean absolute error.

LOL – players	MSE	MAE	r
P6 vs P8	0.89	0.72	0.54
P8 vs P9	1.5	0.87	0.24

Table 2 - Comparison between selected players in Overwatch (OW). MSE – Mean standard error, MAE – Mean absolute error.

OW – players	MSE	MAE	r
P4 vs P5	2.41	1.24	-0.21
P5 vs P6	1.09	0.87	0.44

Discussion

The data collected from participants playing LoL during sessions demonstrates that HRV has high participant variability throughout the entire esports session. Often, changes in HRV will occur at different points of the session for each player. There are moments during play where multiple players appear to have sudden changes in HRV but there is also little consistency in HRV when comparing members of the same team. This is to some extent an expected finding. During games such as LoL and OW, players generally take on different roles creating a high level of unique interests and actions despite team objectives in place. Furthermore, each player will be in a different in-game situation which may be related to a higher or lower level of mental stress which in turn would alter HRV. This is in-keeping with existing research which has considered how HRV is affected by mental tasks or those with cognitive stresses. Studies which more broadly considered the effect of tasks with a high cognitive load have found that HRV does correlate with stress, although how individuals react to the same stimulus varies (22–24,31). One study considering HRV in the context of esports found that there was a significant reduction of RR intervals and high frequency measures of HRV during esports sessions, in-keeping with an increased HR and a stress response, compared to before and after competitive playing, but other measures did not change significantly (26). The changes in HRV which are seen during the session suggest that esports provokes a stress response with variation in sympathetic and parasympathetic activity.

During an esports session there are situations which would be predicted to cause an increase in sympathetic activity leading to a reduction in SDRR in all players, such as team battles or the end phases of play. In our study, as the end of the game approaches there is a reduction in SDRR seen in most players which is expected. Therefore, although there is considerable variation in HRV there appears to be areas of concordance seen in almost all players irrespective of team during play and suggests that certain actions or in-game events create similar patterns in HRV. This finding implies there could indeed be value in using HRV to measure players responses during esports and potential for it to be used generically - although further research is required to identify and characterise these commonalities in order to substantiate such claims. With such differing patterns of HRV over the course of an esports session there may also be the need to individualise or normalise HRV data for each player. Determining points where HRV changes are consistent could be used to calibrate HRV for the individual and allow for easier interpretation of HRV during play. Prior to an esports competition a player could have a set scenario which would induce expected changes in HRV and this could be used as the basis for calibration. Identifying and utilising these periods could be valuable for future research to normalise HRV and allow greater confidence in analysis.

During the session, the winning team demonstrated a lower mean SDRR compared with the losing team suggesting a greater physiological response to play. Previous work considering how other biological parameters, such as HR and RR, change during esports found comparable findings, with players in the winning team exhibiting a greater change in these parameters (32). A study examining 10 pilots' psychophysiological response to a 90 minute scenario showed cardiac measures were related to changes within the simulation, although heart rate was more sensitive than HRV (23). In the context of tasks which invoke mental stress or have a high cognitive load studies have shown that increased time domain measures of HRV are associated with a greater executive function and improved reaction times, memory and attention (33,34). Similarly, acute stress has been linked to impaired memory and a greater number of errors when performing tasks (35,36). Interestingly, our study suggests that the average HRV is lower in the winning team which is in contrast to these studies. However, as discussed earlier, esports is dynamic with rapid changes in scenarios which differ between all players irrespective of teams and this will induce varying levels of stress, alongside in-game situations where all players may be involved, such as team battles. Whilst the mean SDRR across the session is lower for the winning team, this fails to capture the high level of intra-team variation in HRV across the game session and due to the low sample size could be a circumstantial finding. HRV analysis is clearly a sensitive measure and how it correlates with performance will depend heavily on the recording of gameplay alongside HRV to be able to contextualise results. Techniques have been used with benefit in studies concerning cognitive tasks to alter HRV and improve performance. Biofeedback has been studied in the context of cognitive tasks and involves the measurement of physiological parameters, such as HR or HRV, and then this information is made available to the user in real-time, allowing the individual to have greater control over these measures (37). Some studies have shown a benefit of biofeedback associated with improved performance in sport (38–40) and cognitive performance, such as in musicians when performing with reduced errors and improved reaction times (41,42). Measuring HRV in response to esports and using methods to increase HRV could provide a benefit to esports players and is one possible area of further investigation.

HRV has been widely studied in the context of both exercise and cognitive tasks and this study suggests there is possible value in monitoring HRV during esports activity as an objective measure of stress. In the domain of physical activity, the main role of monitoring HRV is to supposedly allow athlete focussed training and improving or measuring performance. Correlating HRV with performance could provide a focus for training and be advantageous for competitive esports players. The recording of in-game data alongside HRV could allow for player-specific information and feedback related to gameplay, team interaction and communication which could provide a target for player development. Providing players with this information may also allow them to have a greater awareness of their physical and emotional response to play and confidence in their ability to perform. Although there are many studies which have considered the use of HRV and its relation to physical activity, there is considerable variation in methodology. Studies have considered diverse populations of participants, different modalities and intensities of exercise with varying measures of HRV and different approaches to analysis (43–45). This, coupled with varying exercise and rest protocols, has meant that scarcely any studies are directly comparable which prevents assessment of conclusions and limits the applicability of studies to sports physiology (6,43). The use of HRV in exercise has been adopted into mainstream sports physiology and use by the general public facilitated by easier methods through which to measure HRV, albeit supported by a vast but inconsistent evidence base. With advancements in wearable devices there is now increasing convenience and practicality in measuring non-invasive physiological parameters, which will inevitably lead to widespread use at a team level without appropriate understanding through research. In fact, availability of these technologies gives a unique opportunity to conduct larger studies with greater confidence in the accuracy of data. At this early stage it is likely that its use in tandem with other collected indices, such as heart rate or respiratory rate, to monitor a stress response would be a more prudent approach. Although the measuring of HRV could represent a powerful tool in esports to monitor stress and cardiovascular response with benefits to performance, further research is required to illicit the relationship and applicability.

This study has a number of limitations. As discussed earlier, the absence of in-game information alongside HRV data prevents further analysis of the relation of changes in HRV and performance. The sample size of this study (n=10) was small, although this is comparable to existing esports studies and this study was designed to provide initial observations of how HRV correlates with esports. Two of the players devices failed to record data due to technical issues with the device and therefore could not be included in the analysis of HRV. Although this study was able to demonstrate that there is variance in HRV across an esports session, baseline HRV, whilst not playing esports, was not recorded for each participant and this would have allowed for a more detailed analysis of how HRV was affected by esports activity.

Earlier research focussed on the use of HRV in relation to disease and found that a reduction in HRV was associated with mortality and a poor prognosis for a number of diseases including myocardial infarction (11,46) and heart failure (13,47,48). However, HRV has not translated well into clinical practice and does not feature in clinical guidelines (49–52) reflecting a lack of understanding of HRV and how it can be utilised in real-world situations. Whilst our research suggests there is possible value in the use of HRV it is clearly very specific to an individual and a high level of study is required in order to produce truly meaningful results.

Conclusion

Our results show that HRV has a moderate level correlation with esports activity, however, it is unlikely to be a useful assessment parameter without a high level of context due to its sensitivity and observer variability.

Funding

The authors received no specific funding for this work.

Declaration of interest

The authors confirm that there are no conflicts of interest to declare.

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