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HRV Monitoring and Recovery Rates: An Experimental Study on Young Tennis Atheltes

Pompilio Cusano[1], Giuseppe Di Lascio[2,3], Kaçurri Arben[4], Kasa Agron[4], Giuseppe Giardullo[2,3]
[1]*Department Nutrition, wellness and sport, Pegaso University of Naples, Italy,*
[2]*Research Center of Physical Education and Exercise, University of Pegaso, Italy,*
[3]*Department of Neuroscience, Biomedicine and Movement, University of Verona, Italy.*
[4]*Sport Univeristy of Tirana, Albania*

Correspondence:
Giuseppe Di Lascio
Research Center of Physical Education and Exercise, University of Pegaso, Italy, giuseppe.dilascio@univr.it

Abstract: *Heart rate variability (HRV) represents time variation between consecutive heartbeats and reflects the ability of the autonomic nervous system to adapt to different stimuli. Despite the growing focus on HRV as indicator of recovery in athletes, there is a lack in scientific literature on how HRV and recovery indices manifest and vary in young tennis athletes, limiting the understanding of physiological dynamics and strategies for optimizing recovery for these athletes. The aim is to identify specific patterns of physiological adaptation during the post-training and competition recovery process. The study aims to understand how HRV characteristics may reflect fatigue, recovery and response to physical stress, with the goal of developing strategies for recovery and performance optimization for this specific population. The study involved 120 young tennis athletes aged 16-18 years old, with 3 years of experience in the sport. The results showed a weak positive correlation with training performance (0.027) and a weak negative correlation with match performance (-0.010). The RMSSD shows weak positive correlations with both training performance (0.013) and match performance (0.031). The LF/HF ratio has a negative correlation with the training performance (-0.206) and there is a weak positive correlation with the match performance (0.110). The results underline the need for a holistic and multifactorial approach to optimize the performance of young tennis athletes. Regular monitoring of HRV provides valuable information on the balance of the autonomic nervous system and the athlete's recovery status but should be complemented by other assessments such as psychological assessments and skill-based tests.*

Keywords: *Heart rate variability, Tennis, young athletes, RMSSD.*

INTRODUCTION

In the current context, sports are recognised for their many psychophysical benefits, which positively affect body and mind (Aliberti, 2023). In physical terms, exercise stimulates the cardiovascular system, promoting better blood circulation, lowering blood pressure and improving respiratory efficiency (Raiola, 2019ab). These effects result in increased endurance, muscle strength and flexibility, which reduce the risk of chronic non-communicable diseases (D'Elia, 2020). It is therefore important to consider the various factors that positively influence a subject's physical development and maintenance (Aliberti et al., 2025). These include heart rate variability (HRV), which represents the time variation between consecutive heartbeats and reflects the ability of the autonomic nervous system to adapt to different stimuli. This physiological parameter is of fundamental importance to evaluate the autonomous regulation of the heart. HRV is closely related to the balance between the two main branches of the autonomic nervous system: the sympathetic nervous system, which accelerates the heartbeat, and the parasympathetic nervous system, which slows it down (Esposito, 2024). Several factors can influence heart rate variability, including age, lifestyle, physical condition and the presence of disease (D'Isanto, 2019ab). For example, HRV tends to decrease with age, reflecting a decrease in the autonomous flexibility of the heart. Chronic stress, lack of sleep and excessive alcohol consumption can also lead to a reduction in HRV. On the other hand, regular physical activity as recommended by the World Health Organization may be useful to prevent HRV reduction (Raiola, 2025). To support the latter, there is also the sports activity, which can develop in the subject the benefits mentioned above (Raiola & Aliberti, 2021). Tennis is a sport that makes the most of these benefits. Tennis is characterized by intermittent and intense efforts, which require adequate preparation in psychophysical terms, focusing especially on skills such as resilience and mental endurance, as well as the capacity to recover energy due to rapid effort (D'Elia et al., 2021; Michel et al., 2023). Due to the type of sport, which alternates moments of explosive activity with short rest periods, athletes are subjected to high physical and cardiovascular pressure, which directly affects their performance and post-match recovery capacity (Esposito et al., 2020; Salierno et al., 2021). In sports, including tennis, HRV is useful for monitoring the state of recovery of athletes, indicating the state of fatigue or overtraining, as well as providing indications to optimize training loads (Ni et al., 2022; Plews et al, 2013). Despite the growing focus on HRV as an indicator of recovery in athletes, current scientific literature has a lack of specific studies concerning young tennis athletes. There is a lack of research exploring how HRV and recovery indices manifest and vary in this specific population, limiting the understanding of physiological dynamics and strategies for optimizing recovery for these athletes. The aim of this study is to analyse in detail the heart rate variability (HRV) in young tennis athletes, in order to identify specific patterns of physiological adaptation during post-workout and post-competition recovery. The research will examine how changes in HRV may indicate fatigue, level of recovery and response to physical stress, with the ultimate aim of developing customized strategies to optimize recovery and improve performance in this athlete population.

METHODS

Study partecipants

The participants in the study are 120 young tennis athletes aged between 16 and 18, with at least 3 years of competitive experience and with a homogeneous level of training. Athletes with pre-existing pathologies that may affect cardiovascular parameters were excluded. The selection will be made through a rigorous process that will include a preliminary check of the general health status, evaluated by means of an exhaustive medical examination.

Study design

Participants have been subjected to a carefully planned monitoring protocol to ensure reliable and meaningful data collection. The methodology followed standardised procedures to ensure consistency and accuracy in the detection of key parameters related to HRV and recovery processes. Monitoring of HRV and recovery indices will be carried out using advanced devices such as wearable cardiac sensors. The monitoring sessions will be scheduled at different times: at rest, during training and during post-exercise recovery. The data collected will include baseline heart rate, HRV and other recovery indices such as heart rate recovery time. Figure 1 provides a level overview of the key elements of the protocol and expected results.

Aspect	Details
Study Duration	8 weeks
Measurement Frequency	Three times a week (Mon, Wed, Fri)
Tools Used	Wearable heart sensors, HRV analysis software, activity tracking apps
Rest Phase	Morning, 10 minutes, supine, wearable sensor
Training Phase	During training, continuous recording
Post-Exercise Recovery Phase	30 minutes post-training, continuous recording
Heart Rate Recovery Time	30 minutes post-training, monitor recovery to baseline
Post-Exercise HR Reduction	First 10 minutes post-exercise, monitor reduction speed
Measurement Tools	Firstbeat sensors, HRV software, tracking apps
Expected Results	Reduced baseline HR, increased HRV, HRV-performance correlation

Figure 1. *Level overview of key elements of the protocol and expected results.*

Several measuring tools were used, including wearable cardiac sensors, defined as accurate devices for heart rate and HRV measurement (Firstbeat).

then, HRV analysis software was used, with specialized applications for the analysis of HRV data (Firstbeat); Physical activity monitoring applications were used, that is tools to track and record training sessions (Firstbeat).

Statistical analysis

After data collection, descriptive statistical methods were applied to obtain an overview of the sample and the main physiological characteristics. Next, a correlation analysis was conducted to examine the associations between HRV parameters and athletic performance, both during training and competition. A correlation matrix was used to evaluate the relationships between resting heart rate, RMSSD, LF/HF ratio, recovery time and reduction of post-exercise heart rate with sports performance.

RESULTS

Following sample recruitment, descriptive statistics were applied to better understand the sample itself, as can be analysed in Figure 2**.**

Statistic	Value
Number of Participants	120
Average Resting Heart Rate (bpm)	60.50
Average RMSSD (ms)	77.68
Average LF/HF Ratio	1.38
Average Recovery Time (min)	8.20
Average Post-Exercise HR Reduction (bpm)	20.40
Average Training Performance Score	86.02
Average Match Performance Score	89.49

Figure 2. *Descriptive statistical application.*

The correlation matrix was then used, as shown in Figure 3.

Variable	Resting HR	RMSSD	LF/HF	Recovery Time	Post-Exercise HR Reduction	Training Performance	Match Performance
Resting Heart Rate (bpm)	1.000	0.098	-0.110	-0.043	0.014	0.027	-0.010
RMSSD (ms)	0.098	1.000	0.126	-0.067	0.015	0.013	0.031
LF/HF Ratio	-0.110	0.126	1.000	-0.057	0.030	-0.206	0.110
Recovery Time (min)	-0.043	-0.067	-0.057	1.000	-0.014	-0.061	0.066
Post-Exercise Heart Rate Reduction (bpm)	0.014	0.015	0.030	-0.014	1.000	-0.127	0.024
Training Performance Score	0.027	0.013	-0.206	-0.061	-0.127	1.000	0.049
Match Performance Score	-0.010	0.031	0.110	0.066	0.024	0.049	1.000

Figure3. Correlation *matrix*

From Figure 3 it is possible to notice that for the heart beats at rest there is a very weak positive correlation with the performance in training of the value 0.027 and a very weak negative correlation with the performance in game of the value -0.010, indicating a minimal association with athletic performance. Next there is the RMSSD, which shows very weak positive correlations with both the performance in training with a value of 0.013, and in game with a value of 0.031, representing a minimal association with the performance. Continuing there is the LF/HF ratio, where there is a negative correlation with the training performance from the value of -0.206. In addition, there is a weak positive correlation with the performance of the 0.110 lot. Next, there is the recovery time section, which shows a very weak negative correlation with training performance from the value of 0.061 and a weak positive correlation with match performance from the value of 0.066. Finally, there is the section of the reduction of the heart rate post-exercise, which shows a very weak negative correlation with the performance in training by the value of -0.127 and a very weak positive correlation with the match performance of 0.024. Then, individual dispersion graphs were reported for each physiological variable with respect to the performance parameters, representing:

Resting heart rate (bpm) vs training performance score (Graph1); Resting heart rate (bpm) versus match performance score (Graph 2); RMSSD (ms) vs Training Performance Score (Graph 3); RMSSD (ms) versus match performance score (Graph. 4); LF/HF versus training performance score (Graph. 5); LF/HF vs Match Performance Score (graph. 6); Recovery time (min) vs performance score (Graph. 7); Recovery time (min) against the match performance score (Graph. 8); Reduction in post-exercise heart rate (bpm) compared to training performance score (Graph. 9); Reduction in post-exercise heart rate (bpm) compared to match performance score (Graph. 10).

Discussion

The results of this study show weak correlations between physiological parameters and athletic performance, suggesting that although these indicators are useful for monitoring general physical condition and recovery, are not sufficiently predictive of performance in training or competition. One relevant aspect is the correlation between resting heart rate and athletic performance. The values obtained (0.027 for training and -0.010 for competition) indicate a negligible impact of this parameter on performance. This confirms previous results that demonstrate that HRV, while providing information on the state of fatigue and recovery, is not an isolated indicator to predict an athlete's performance. A more holistic approach is therefore needed, which considers several factors in addition to cardiovascular parameters. The RMSSD, considered an index of heart rate variability, showed equally weak correlations with both training performance (0.013) and match performance (0.031). Again, the high variability does not seem to translate directly into better athletic performance. Previous studies (Buchheit, 2014) have confirmed that a high HRV is indicative of better adaptability to physical stress, but this is not always reflected in field performance as other factors come into play. The LF/HF ratio, which reflects the balance between the sympathetic and parasympathetic nervous systems, showed a negative correlation with performance in training (-0.206) and a positive but weak correlation with match performance (0.110). This suggests that a better autonomic balance could help improve competitive performance, although the association is marginal. These results are in line with studies that highlight how autonomic stress management and post-workout recovery are crucial factors for athletes' preparation for competitions (Sandercock et al., 2005). Recovery time and reduced heart rate after exercise showed weak correlations with both training and match performance. This data supports the idea that, although HRV can provide useful indications for monitoring recovery status, athletic performance is the result of a complex interaction between physiological, psychological and technical factors (Stanley et al., 2013). One of the main limitations of this study is the sample. Although 120 participants represent a good data set, larger and more diverse samples could provide more robust and generalizable results. In addition, individual differences in physiology and training response may have affected the results, limiting the universal applicability of conclusions. Factors not considered in this study, such as diet, sleep, mental state and technical ability, also play a crucial role in determining athletic performance and could be explored in future research for a more complete understanding. Future research could focus on a multidimensional approach, combining physiological, psychological and technical data to develop more effective training and recovery strategies.

Conclusion

The study highlights the complex nature of athletic performance and the limited role that individual physiological parameters play in isolation. The HRV and recovery indices, although useful, are not sufficient in themselves to predict performance. The results underline the need for a holistic and multifactorial approach to optimize the performance of young tennis athletes. Regular monitoring of HRV provides valuable information on the balance of the autonomic nervous system and the athlete's recovery status but should be complemented by other assessments such as psychological assessments and skill-based tests. Coaches and sports scientists should use HRV data as part of a broader set of parameters to make informed decisions about training loads and recovery strategies. The study also highlights the importance of longitudinal monitoring. Collecting data over extended periods can help identify trends and patterns in an athlete's physiological responses, allowing better prediction and management of performance and recovery. This long-term approach is essential for the development of training methodologies that adapt to the changing needs of the athlete. By regularly monitoring HRV, coaches can identify signs of burn-out and take timely action to adapt training plans accordingly. In conclusion, the study provides valuable information on the use of HRV and recovery rates to optimize athletic performance. Although these parameters are important, they should be part of a comprehensive monitoring strategy that includes various physical, psychological and competency-based assessments. Regular, personalized monitoring, combined with the use of advanced technologies, can increase training effectiveness, improve performance and ensure the well-being of young athletes.

Conflict of interest
The authors declare that there is no conflict of interest.

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