

Heart rate variability features and their impact on athletes' sports performance

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Abstract:

Problem statement: The relationship between heart rate variability (HRV) indicators and athletic performance is a subject of interest in sports science. However, few studies have explored the differences in HRV parameters between high-level athletes and athletes without significant sport success, impeding our understanding of the physiological characteristics associated with sport performance. **Approach:** A cross-sectional study was conducted involving two groups: high-level athletes (Group A) and athletes without sport success (Group B). HRV assessment was performed on 33 athletes using the Varicard 2.51 complex to measure HRV parameters. Time domain and spectral analyses were employed to calculate and compare HRV parameters between the two groups. **Purpose:** In this study, we aimed to investigate the functional state features of athletes as an indicator of sport success. **Results:** Significant differences in HRV parameters were found between Group A and Group B athletes. Group B athletes exhibited higher mean values in Standard deviation (SDNN), Stress Index (SI), Index of activity of regulatory systems (IRSA), high-frequency power (HF), and low-frequency power (LF), indicating increased autonomic regulation, tension in regulatory systems, and heightened activation of the autonomic nervous system. Conversely, Group B athletes displayed lower mean values in very low-frequency power (VLF), suggesting reduced activity in thermoregulation and energy exchange centers. Independent t-tests revealed significant differences in IRSA, NArr, and VLF parameters, with Group B showing pronounced tension in regulatory systems, and decreased activity in thermoregulation and energy exchange centers. **Conclusions:** This study emphasizes the importance of analyzing HRV when assessing an athlete's functional state and understanding physiological characteristics associated with different levels of sport success. Athletes without significant sport success exhibit distinct differences in autonomic regulation, parasympathetic activity, thermoregulation, and energy exchange compared to high-level athletes. These findings underscore the potential impact of sport success on athletes' physiological responses and highlight the need for HRV monitoring and individualized training approaches. Further research is required to explore underlying mechanisms and develop interventions to enhance the performance of athletes without sport success.

Keywords: heart rate variability, athletic performance, autonomic regulation, sport success, physiological characteristics, sport physiology

Introduction

Sport evaluation plays a vital role in optimizing an athlete's performance by providing coaches with valuable insights into the factors influencing athletic success. To achieve this, a comprehensive understanding of various factors, including genetic attributes (Sarzynski & Bouchard, 2020; Sarmiento et al., 2020), training capacity, sport technique, health status, and psychological factors (Lai et al., 2020; Pang et al., 2020), is crucial for designing effective training programs and enhancing competitive abilities (D'Isanto et al., 2019). By combining an athlete's physiological characteristics with their functional state, coaches can conduct thorough assessments to tailor training strategies effectively. In the field of sports science and performance optimization, the assessment and diagnostics of the functional state in young athletes hold immense relevance. This understanding of the multiple factors influencing athletes' performance is essential for designing effective diagnostic programs and evaluation criteria. Contemporary research methodologies emphasize a system approach and complexity in functional diagnostics, emphasizing key factors that determine the effectiveness of athletes' competitive activities (Kuznetsov et al., 2017). By selectively choosing informative modern methods and means of diagnosis, incorporating varying physical loads, and identifying the key components of functional training, sports professionals gain valuable insights into optimizing athletes' potential and overall performance.

Furthermore, the concept of the optimal functional state of the sportsperson (OFSS) has garnered significant attention in modern sport physiology and medicine. Researchers such as Isaychev et al. (2012), Volodchenko et al. (2017), and Zubaydullaeva & Karimova (2021) have explored this phenomenon, highlighting its importance in considering not only physical or physiological perfection but also the development of psychophysiological and psychological qualities specific to different sports. Continuously monitoring OFSS

dynamics during training and competitions enables a comprehensive understanding of athletes' deviations from optimum performance, leading to predictions of potential reductions in their sport efficiency (Korobeynikov et al., 2006). As sport and exercise psychology (SEP) has increasingly adopted physiological markers, heart rate variability (HRV) has emerged as a valuable technique to understand athletes' self-regulation and adaptation (Mosley & Laborde, 2022). HRV provides non-invasive insights into the cardiac autonomic nervous system (ANS) and its balance between sympathetic and parasympathetic branches (Mejía-Mejía et al., 2020; Kuznetsova et al., 2015). It serves as a crucial marker for evaluating the functional state (FS) of athletes and offers a comprehensive view of various regulatory mechanisms, enabling a holistic understanding of athletes' FS (Guzii & Romanchuk, 2018). Athletes can utilize HRV parameters to manage physical fatigue, adjust exercise intensity, and personalize training regimens for optimal performance and avoiding overtraining. Notably, the distinct HRV profiles exhibited by athletes compared to sedentary individuals further highlight the relevance of HRV in sports physiology (Dong, 2016).

Numerous studies have explored the application of HRV in sports science, shedding light on its potential as a valuable tool. For instance, HRV has been used in studies of endurance sports like cycling to examine changes during multi-day events such as the Tour of Spain (Earnest et al., 2004). The research findings demonstrated that increased exercise intensity negatively correlated with HRV parameters, indicating decreased HRV and a shift in the sympathovagal balance towards sympathetic activity during heightened physical stress. This suggests that HRV may be strongly influenced by chronic exposure to heavy exertion, with training volume and intensity playing a significant role in determining the degree of these alterations. HRV has also been studied in relation to sex differences and cardiovascular health in badminton athletes (Tai et al., 2022). The study revealed potential gender-specific variations in HRV and cardiovascular health among athletes participating in different sports disciplines. Additionally, HRV dynamics during recovery after high-intensity exercise interventions in endurance athletes have been explored, highlighting the importance of understanding HRV changes during different recovery phases to optimize training and recovery strategies for athletes.

Moreover, some research studies have delved into HRV as a performance indicator in sports, offering insights into its potential to enhance athletes' training and competitive outcomes. Ortega and Wang (2017) focused on shooters and identified a significant positive correlation between HRV, self-efficacy, and shooting performance. This research highlighted HRV's capacity as an objective tool to quantify an athlete's physiological state before competition, thereby leading to improved performance through practical strategies. Conversely, D'Ascenzi et al. (2014) examined elite female volleyball players and observed a significant decrease in autonomous HRV and an increase in the central regulation loop as they approached decisive matches. The researchers proposed that HRV monitoring could be a valuable method to assess athletes' competitiveness, with reductions in HRV potentially indicating better performance outcomes. In contrast, Kiss et al. (2016) focused on HRV differences between healthy elite and masters athletes and non-athletic controls. They found significant variations in autonomic regulation patterns between athletes, offering insights into HRV's potential as a marker to distinguish performance levels and its relevance in risk stratification and training optimization.

While HRV has shown great promise in sports science, standardization of methodologies and further research are necessary to fully capitalize on its potential in sports training (Makivić et al., 2013). Integrating HRV assessments with other physiological and psychological markers will provide coaches with a comprehensive understanding of an athlete's functional state, leading to informed decisions that enhance overall performance. The exploration of HRV variations among athletes with diverse levels of sport success is also warranted to deepen our understanding of its association with athletic performance. As research continues to shed light on HRV's versatility and applications, it is poised to become an increasingly valuable tool in the quest for peak athletic performance.

The aim of this research: to investigate the features of the functional state of athletes as an indicator of sports success.

Material & methods

Participants: The study included a total sample of 33 athletes who met the following inclusion criteria: (1) absence of known cardiovascular or respiratory diseases, (2) no current use of medications that could potentially affect heart rate variability, and (3) willingness to participate in the study. The participants were divided into two main groups based on their level of sports success. The athletes represented various disciplines, including gymnastics (2), weightlifting (3), shooting (4), judo (4), boxing (10), and wrestling (10).

Group A consisted of 15 high-class athletes, including 3 women and 12 men, with an average age of 24.3 years (± 2.53). All athletes in Group A were gold medalists of the championship of Armenia, with two athletes simultaneously holding European championship titles. Additionally, 4 athletes were silver medalists, and 6 athletes were bronze medalists in the European championship. Three athletes had silver medals and 5 athletes had bronze medals from the World Championship. The selection of athletes for Group A was based on their exceptional achievements in their respective sports disciplines, ensuring a representative sample of high-level athletes in Armenia.

Group B comprised 18 athletes who had not achieved significant sports success. Among the participants, there were 6 women and 12 men, with an average age of 20.6 years. This diverse group of athletes served as a

comparison to evaluate the differences in heart rate variability between athletes with different levels of sports success.

Procedure: All participants' heart rate variability (HRV) measurements were conducted in the morning, at approximately the same time, at the Sport EMI Scientific Research Center of the Armenian State Institute of Physical Culture and Sport. Prior to the measurements, participants were instructed to refrain from consuming stimulants such as caffeine and to avoid intense physical activity for at least 12 hours. The HRV was recorded in resting state in sitting position (5 minutes).

Instruments and Measurements: The assessment of cardiac variability was conducted using the Varikard 2.51 device, a widely used system for measuring HRV. The device has an input voltage range of 0.3 mV to 5 mV, with estimated deviations of $\pm 14\%$ for stress estimation and $\pm 10\%$ for time intervals. The following heart rate variability indicators were analyzed during the study to assess the athletes' physiological state:

- Standard deviation - SDNN (ms): Reflects the overall effect of autonomic regulation of blood circulation.
- Coefficient of variation - CV (%): A normalized indicator of the overall effect of regulation.
- Stress index - SI: Indicates the degree of tension in regulatory systems.
- Centralization index - CI: Reflects the degree of centralization of heart rate regulation.
- Index of activity of regulatory systems - IRSA: Provides information about the activity of regulatory systems.
- Number of arrhythmias - Narr (%).
- High-frequency power - HF power (%): Reflects the relative level of activity of the parasympathetic regulation.
- Low-frequency power - LF power (%): Reflects the relative level of activity of the vasomotor center.
- Very low-frequency power - VLF power (%): Reflects the relative level of activity of the regulatory sympathetic connection.
- Total power of heart rate variability - TR: Represents the overall level of activity of regulatory systems. (Stepanyan & Asriyan, 2022)

Statistical Analysis: The HRV data were collected using the Varicard 2.51 device, and the recorded data were subjected to preprocessing steps, including filtering and artifact removal, to ensure data quality. The relevant HRV parameters were then calculated from the cleaned data.

The ISCIM6 software was utilized for HRV data analysis, and statistical analysis was performed using the SPSS software. Descriptive statistics, including means and standard deviations, were calculated for each HRV parameter in both Group A and Group B. Independent t-tests were conducted to compare the HRV parameters between the two groups. The significance level was set at $p < 0.05$ to determine statistical significance.

Results

Statistical analysis was performed to compare the heart rate variability (HRV) parameters between the two research groups: high-level athletes (Group A) and athletes without significant sport success (Group B). The mean values of various HRV parameters were computed for each group and presented in Table 1.

Table 1. Mean Values of HRV parameters on Group A (high-level athletes) and Group B (Athletes without sport success)

HRV Parameter	Group	Mean	Std. Deviation	Normal Range
HR	Group A	71.0667	9.21541	60-74.9
	Group B	70.0556	16.20629	
SDNN	Group A	71.2467	28.89429	30-100
	Group B	84.6667	39.31680	
CV	Group A	8.0867	2.35004	3-12
	Group B	9.1222	3.39334	
SI	Group A	91.0000	110.50016	50-150
	Group B	123.7222	250.14438	
IC	Group A	4.6533	5.61425	2.0-8.0
	Group B	2.9278	2.40216	
IRSA	Group A	3.8667	1.45733	1-3
	Group B	5.9444*	2.04284	
NArr	Group A	1.1533	1.59386	0-4
	Group B	2.3333	3.18156	
HF	Group A	29.0533	15.14251	10-30
	Group B	33.8944*	17.40424	
LF	Group A	44.4067	10.26286	15-45
	Group B	49.6000*	15.41893	
VLF	Group A	27.6067	17.30757	20-60
	Group B	16.4833*	10.51359	
TR	Group A	4401.1333*	2887.93312	800-1500
	Group B	6485.2778*	4938.70750	

Note: *Values deviated from the normal range

The comparison of group means for heart rate variability indicators revealed differences between high-level athletes (Group A) and athletes without sport success (Group B). Notably, both groups exhibited values within the normal range for SDNN and SI, indicating a level of physiological regulation. However, a closer analysis revealed a considerable difference between the two groups in these parameters, with Group B displaying higher mean values than Group A.

Additionally, when examining IRSA, HF, LF, and VLF indicators, Group A athletes' mean values fell within the normal range, while the mean values of Group B athletes deviated from the normal range. Specifically, Group B exhibited higher mean values in IRSA, HF, and LF, indicating increased activation of the autonomic nervous system. Furthermore, Group B showed lower mean values in VLF, suggesting reduced activity in thermoregulation and energy exchange centers.

To further investigate the differences between the two study groups, an independent t-test was performed to compare specific heart rate variability indicators. The results revealed significant differences between high-level athletes (Group A) and athletes without sport success (Group B) in terms of IRSA, NArr, and VLF parameters. Specifically, Group B exhibited significantly higher mean values in IRSA ($t = -3.298$, $p = 0.002$), indicating pronounced tension in the regulatory systems compared to Group A. Similarly, Group B displayed a significantly higher mean value in NArr ($t = -2.848$, $p = 0.11$), suggesting a higher occurrence of arrhythmias. Additionally, Group B exhibited a significantly lower mean value in VLF ($t = 2.177$, $p = 0.040$), indicating decreased activity in thermoregulation and energy exchange centers.

It is important to note that no significant differences were observed between the two groups for other heart rate variability parameters, including SDNN, SI, HF, and LF (all $p > 0.05$). These findings suggest that while overall differences exist between the groups in terms of select heart rate variability indicators, other parameters may not be significantly influenced by the athletes' level of sport success.

Table 2 provides a summary of the independent t-test results, including the t-values and corresponding p-values for each parameter, further highlighting the observed differences between the two groups.

Table 2. Summary of Independent t-Test Results for Heart Rate Variability Indicators

HRV Parameter	t	Sign (2-tailed)
HR	.225	.824
SDNN	-1.128	.268
CV	-.998	.326
SI	-.469	.642
IC	1.183	.246
IRSA	-3.298	.002*
NArr	-2.848	.011*
HF	-.843	.406
LF	-1.114	.274
VLF	2.177	.040*
TR	-1.508	.143

Note: * $p < 0.05$ (significance level)

Discussion

The purpose of this study was to examine the features of the functional state of athletes as an indicator of sports success, specifically by comparing heart rate variability (HRV) parameters between high-level athletes (Group A) and athletes without significant athletic performance (Group B). The analysis of HRV parameters revealed interesting differences between the two groups, shedding light on their physiological characteristics and autonomic regulation patterns.

In terms of the SDNN and SI indicators, which reflect general autonomic regulation and the degree of tension in regulatory systems, both groups exhibited values within the normal range. However, it is important to consider the age and sex characteristics when evaluating the results of the study. Therefore, we assessed the changes in the indicator values compared to the average values of their respective groups.

SDNN is a simple statistical analysis procedure for HRV, and its values are expressed in milliseconds (ms). An increase in SDNN, as observed in the results of Group B, indicates enhanced autonomic regulation, particularly an increased influence of breathing on the heart rhythm, often observed during sleep. Further analysis has been conducted according to the HRV analysis system recommended by Baevsky and Chernikova (2017). The stress index indicator (SI) reflects the degree of tension in regulatory systems. SI characterizes the activity of sympathetic regulation mechanisms and the state of the central circuit of regulation. This indicator is highly sensitive to an increase in sympathetic nervous system tone. Even a small physical or emotional load can increase SI by 1.5 to 2 times during mental or physical exertion. The results reveal that Group B exhibited higher SI values compared to Group A, indicating an activation of the central circuit and increased sympathetic regulation. The higher mean values of SDNN and SI in Group B athletes compared to Group A suggest slightly higher overall autonomic regulation and increased tension in their regulatory systems.

The results of the spectral analysis parameters, specifically HF and LF, differ between the two groups of athletes. Group B exhibits increased values for both parameters, which are outside the normal range.

The frequency range HF predominantly represents the parasympathetic influence on heart rate. The activity of the sympathetic division of the autonomic nervous system, as a component of the autonomic balance, can be evaluated based on the degree of inhibition of the autonomous regulatory circuit, which is controlled by the parasympathetic division. Vagal activity is the main component of the HF spectrum. This effectively reflects the power of respiratory waves in heart rate, both in absolute terms and as a relative value (expressed as a percentage of the total power of the spectrum). In our study, the extremely high values of HF indicators in Group B indicate parasympathetic dominance within this research group.

On the other hand, the low-frequency power (slow waves of the first order or vasomotor waves, LF) specifically characterizes sympathetic nervous activity and the vascular tone regulating system. Although many Western researchers consider this parameter as a marker of sympathetic modulation of heart rate, there are compelling arguments suggesting that slow waves of the first order with a period of 10–20 seconds characterize the state of the vascular tone regulation system. The vasomotor (vascular) center, along with the inhibitory and stimulating sympathetic centers, is part of the modulatory cardiovascular subcortical center. The power of slow waves of the first order determines the activity of the vasomotor center, while the power of slow waves of the second order is associated with the activity of sympathetic centers controlled by higher levels of regulation. An increase in the power of slow waves to 13–14 seconds may indicate a decrease in the activity of the vasomotor center or a slowdown in the processes of baroreflex regulation.

These differences suggest a trend towards higher parasympathetic activity and activation of the vasomotor center in athletes without significant athletic performance. While no significant differences were observed in parameters such as SDNN, SI, HF, and LF, it is important to note that these parameters may still provide valuable insights into the autonomic regulation and functional state of athletes, even if differences were not statistically significant in this study. The lack of statistical significance could be attributed to the sample size or individual variations within the groups.

The statistical analysis reveals a significant difference between the two research groups in terms of VLF and IRSA indicators. The very low-frequency range (VLF) represents slow waves of the 2nd order, and an increase in VLF power suggests more intensive sympathetic activity and suprasegmental regulation. The significance of HRV in the VLF power range, particularly its sensitivity as an indicator of metabolism regulation and energy-deficient states. While many foreign authors associate VLF with the activity of the sympathetic division of the autonomic nervous system, in this case, it reflects more complex influences from the suprasegmental level of regulation, including psycho-emotional stress. There is evidence supporting VLF as a sensitive indicator of the control of metabolic processes and its ability to reflect energy-deficient states. Thus, VLF parameters characterize the influence of higher autonomic centers on the cardiovascular subcortical center and serve as a reliable marker of the degree of connection between autonomous (segmental) levels of blood circulation regulation and suprasegmental levels, such as the pituitary-hypothalamic and cortical levels. The lower mean values in VLF observed in Group B indicate reduced activity in thermoregulation and energy exchange centers. The decrease in VLF power among athletes without significant sport success may indicate a disruption in the balance between sympathetic and parasympathetic activity, potentially impacting their physiological adaptability and performance.

VLF is a fundamental indicator that has been related to sport performance in various other research studies. For example, Diverky et al. (2013) found a significant relationship between peak VLF and badminton performance levels when measured after matches. Players who achieved better results in matches had significantly higher average VLF power values compared to those who lost most of their matches. VLF appears to be more prominent in the absence of parasympathetic stimulation and in the presence of higher sympathetic stimulation. D'Asenzi et al. (2014) demonstrated that the relative VLF power of elite volleyball players significantly increased on the day of the decisive match compared to the previous two days, linking this change to physiological and psychological effects of pre-competition stress. However, there is no definitive consensus on the exact role of VLF power as an indicator of autonomic nervous system activity and, importantly, its relationship with athletic performance. Similar to these previous studies, our research also found a significant difference in VLF between the two groups.

The second significant difference between the two research groups is related to the comprehensive assessment of the functional state using the activity of regulatory systems (IRSA) indicator. IRSA provides a comprehensive evaluation of heart rate variability and is used to diagnose functional conditions rather than diseases. Changes in the autonomic balance, specifically the activation of the sympathetic branch, are considered a nonspecific component of the adaptive response to various stressors. The calculation of IRSA involves a special algorithm that takes into account multiple statistical indicators, histogram indicators, and spectral analysis data of cardiac intervals.

IRSA serves to differentiate different degrees of tension in regulatory systems and evaluate the adaptive capabilities of the body. It is calculated based on five criteria:

1. The total effect of regulation based on pulse rate indicators.
2. The overall activity of regulatory mechanisms measured by SDNN (or TP).
3. Vegetative balance assessed through a set of indicators such as SI, RMSSD, HF, and IC.

4. The activity of the vasomotor center, responsible for regulating vascular tone, based on the power of the spectrum of slow waves of the 1st order (LF).
5. The activity of the cardiovascular subcortical nerve center or suprasegmental levels of regulation indicated by the power of the spectrum of slow waves of the 2nd order (VLF).

In our research, Group A exhibited a state of moderate tension in regulatory systems, indicating that the body requires additional functional reserves to adapt to environmental conditions. Such conditions typically arise during work adaptation, emotional stress, or exposure to adverse environmental factors. On the other hand, Group B demonstrated a state of pronounced tension in regulatory systems, indicating active mobilization of protective mechanisms, including an increase in the activity of the sympathetic-adrenal system and the pituitary-adrenal system.

The significant difference in IRSA between the two groups suggests distinct variations in the adaptive capabilities and regulatory states of the athletes. Group B appears to exhibit a higher level of physiological tension and activation of stress response mechanisms compared to Group A.

Furthermore, Group B athletes exhibited a higher occurrence of arrhythmias (NAr) compared to Group A athletes. This finding suggests a potential disruption in the normal rhythm of the heart among athletes without significant sport success, which may be associated with increased sympathetic activity or other physiological imbalances.

The differences observed in heart rate variability (HRV) parameters between high-level athletes and athletes without significant sport success can be attributed to physiological adaptations (Plews et al., 2013; Fatissou et al., 2016). Successful athletes undergo extensive training and physical conditioning, which leads to specific physiological changes. These adaptations can include improvements in cardiovascular function, enhanced aerobic capacity, and optimized autonomic regulation. The rigorous training and physical demands of high-level sports stimulate physiological responses that promote better HRV patterns. These adaptations allow athletes to efficiently regulate their heart rate and autonomic nervous system, resulting in more favorable HRV measurements. Overall, the observed differences in HRV parameters provide valuable insight into the physiological characteristics and autonomic regulation associated with different levels of athletic success. These findings highlight the potential impact of athletic performance on autonomic responses, thermoregulation, energy metabolism, and the occurrence of arrhythmias in athletes.

The present study contributes to the growing body of research on HRV and its association with athletic performance. By comparing HRV profiles between high-level athletes and athletes without significant sport success, this study expands our understanding of the physiological differences between these groups. The findings emphasize the importance of HRV analysis as a non-invasive tool for assessing athletes' functional states and physiological adaptations. Further research in this area could explore the long-term effects of sport success on HRV and its implications for optimizing athletic performance and designing effective training programs.

However, it is essential to acknowledge some limitations of this study. Firstly, the sample size was relatively small, which may limit the generalizability of the findings to larger populations. However, it is important to note that the sample used in this study was representative of elite athletes in Armenia. Additionally, the study design was cross-sectional and focused on resting HRV measurements. Future research should consider incorporating HRV assessments during different exercise intensities or under specific training conditions to gain a more holistic understanding of the relationship between HRV and athletic performance.

Conclusions

Based on the findings of this study, several conclusions can be drawn regarding the relationship between heart rate variability (HRV) parameters and sports success in athletes:

1. **Autonomic Regulation:** Athletes without significant sport success exhibited slightly higher overall autonomic regulation and increased tension in their regulatory systems compared to high-level athletes. This suggests that autonomic responses may vary between athletes with different levels of sports success.
2. **Parasympathetic and Vasomotor Activity:** Athletes without significant athletic performance displayed higher parasympathetic activity and vasomotor center activation compared to high-level athletes, although the differences were not statistically significant. This indicates a trend towards heightened parasympathetic and vasomotor responses in athletes without significant sport success.
3. **Thermoregulation and Energy Exchange:** Athletes without significant sports success showed reduced activity in thermoregulation and energy exchange centers compared to high-level athletes. Impaired thermoregulation and energy metabolism in these athletes may affect their overall physiological adaptation.
4. **Regulatory System Tension:** Athletes without significant sport success exhibited pronounced tension in their regulatory systems, as indicated by significantly higher mean values in the index of activity of regulatory systems (IRSA). This suggests higher levels of autonomic tension and potential challenges in maintaining regulatory balance in these athletes.

Overall, these findings highlight the potential impact of sports success on athletes' autonomic responses, thermoregulation and energy metabolism. The differences observed in HRV parameters between high-level athletes and athletes without significant sport success can be attributed to variations in physiological adaptability. These findings underscore the importance of HRV monitoring and individualized training approaches in optimizing performance and overall well-being in athletes without sport success. Future research should focus on elucidating the underlying mechanisms and exploring targeted interventions to improve autonomic balance and enhance performance outcomes in this population.

Conflicts of interest - The authors declare no potential conflict of interest.

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