INVESTIGATION OF HEART RATE VARIABILITY DURING RECOVERY AFTER COMPETITION PERFORMANCE IN ARTISTIC GYMNASTICS RING APPARATUS

ARTİSTİK CİMNASTİK HALKA ALETİNDE YARIŞMA PERFORMANSI SONRASI TOPARLANMA SÜRECİNDE KALP ATIM HIZI DEĞİŞKENLİĞİNİN İNCELENMESİ

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Objective: The aim of the study was to investigate in detail the performance physiology and recovery physiology during and after the elite level men's artistic gymnastics ring competition series by observing heart rate and heart rate variability.

Method: Men's artistic gymnastics Turkish national team athletes aged 18 years and older participated in the study. The participating athletes included Turkish athletes who won gold medals in the last 2 World Championships in 2020 and 2023. Athletes were measured at rest for 10 minutes before the competition performance. During rest, heart rate and heart rate variability parameters were recorded. After the resting measurements were completed, the measuring devices were removed. After 30 minutes of individual free warm-up, the measuring devices were reinserted and recovery measurements were performed for 5 minutes after the series in the athletes who performed their series on the ring machine. Heart rate and heart rate variability parameters were recorded during recovery.

Results: Heart rate values were high at the beginning (148.7) and end (177.1) of the competition series performed by gymnasts. RR values showed high variability in the first 2 minutes during recovery after the series ($p<0.05$).

Conclusion: The results of the study indicate that heart rate variability during 5 minutes of acute recovery after a series of isometric and dynamic contractions with predominantly upper body muscle groups on the artistic gymnastics ring apparatus shows a high level of variability.

Key Words: Artistic Gymnastics; Heart Rate Variability; Rings

1. Introduction

Artistic gymnastics, which has been part of the modern Olympic calendar since 1896, is currently one of the most popularly watched disciplines. Its popularity stems from evolving into a spectacle that combines high-level technical skills with excited and a focus on flawless performance (Güler, 2005). In recent years, there has been a notable increase in the contribution of physical strength and power to gymnastic performance (Jemni et al., 2001). While evaluating gymnasts' performance through choreographic routines and acrobatic movements on the ring apparatus, the physiological responses of athletes during these processes should also be considered (Mkaouer et al., 2018). Heart rate (HR) and heart rate variability (HRV), which are physiological components of performance, reflect time variations between consecutive heartbeats and are also consequences of dynamic, nonlinear autonomic nervous system processes. Analysis of HRV can provide indirect information about the autonomic function of the cardiovascular system and allows us to assess sympathetic and parasympathetic activity (Aubert et al., 2003; Freeman et al., 2003; Kingsley & Figueroa, 2016). Currently, HRV has become one of the most useful tools for monitoring athletes' training adaptation and maladaptation over time and for adjusting optimal training loads leading to performance enhancement (Dong, 2016).

In the context of this information, a systematic investigation of heart rate variations during and after performances on the artistic gymnastics ring apparatus is important for understanding these processes. This study aims to provide important theoretical and practical contributions in the fields of sports sciences and ring apparatus performance physiology and to help us better understand the physiological responses of athletes during competition performances and recovery processes afterwards.

2. Materials and Methods

This study was approved by the Marmara University Faculty of Medicine Clinical Research Ethics Committee under protocol number 09.2022 1053.

Male athletes aged 18 years and older who were members of the national artistic gymnastics team at the international elite level participated in the study on a voluntary basis. There were a total of N=10 Turkish gymnasts in the study. Since the maximum number of athletes in the men's artistic gymnastics senior category in Turkey who can compete on the rings is 10, the number of participants in the study was limited to 10. Among the participating athletes, there are two Turkish gymnasts who won gold medals at the 2019 and 2023 World Championships and achieved success in reaching the finals at the 2021 Tokyo Olympic Games. No injuries or adverse conditions were observed in the athletes before or after their performance.

In this study, a heart rate monitor chest strap (Polar, H10) was used throughout the measurement to track the athletes' heart rates. Heart rate data were recorded in the R-R interval. First, the athletes' initial 10-minute rest measurements were taken with an eye mask and headphones to isolate them from sound and light. Heart rate and heart rate variability parameters were recorded while the athletes were in the supine position. Sound and light stimuli increase sympathetic activity and affect the autonomic nervous system in heart rate variability measurements, so isolation was provided with an eye mask and headphones. After completing the rest measurement, each athlete was given a 30-minute personal warm-up period. The reason for this is that artistic gymnastics requires high concentration to perform very risky movements. Since warming up with specific movements restricted by the researcher would negatively affect the preparation process for elite athletes with different personal rituals, warm-ups were limited only by time.

After a 30-minute free warm-up, athletes performing their routines on the apparatus were placed back in the supine position after the final movement of the routine. Heart rate and heart rate variability measurements continued for 5 minutes during the recovery period, isolated from sound and light. All measurements were performed on the same day and under the same environmental conditions.

3. Analysing The Data

The athletes’ resting heart rate values were recorded during the initial 10-minute rest period. Preliminary test trials were conducted to evaluate heart rate measurements during ring-exercise conditions. Measurements obtained using different devices revealed similar patterns of artifact signals caused by high-intensity muscle contractions. In the main measurements, athletes likewise performed high-intensity isometric contractions and demanding elements during the rings routine. These strong contractions, associated with substantial muscle mass activation, produced distorted signals on the chest-worn HR strap. Because these artifacts were not suitable for correction or reliable analysis, the heart rate data recorded during exercise could not be used. Data inspection showed that heart rate signals returned to normal immediately after the routine ended, a pattern consistently observed in all athletes. Similar findings were noted during the pre-tests. Given that the available technology was insufficient to distinguish cardiac electrical activity (HR and R-R signals) from the mechanical and electrical interference produced by intense chest-region muscle contractions during the routine, in-routine HRV data were excluded from analyses. For the analysis of HR, R-R intervals, and RMSSD during post-routine recovery, the Kubios HRV Scientific Lite 4.1 software was used. Maximum, minimum, and mean HR values were recorded, while mean values were used for R-R and RMSSD. In the statistical analysis, descriptive characteristics and physical and physiological parameters specific to the discipline were summarized using minimum, maximum, and standard deviation values. Mean HR, mean R-R interval, and mean RMSSD values were obtained at rest, before the competition routine, and after the routine. HR, R-R, and RMSSD data were analyzed using the Friedman Repeated-Measures ANOVA test in the Jamovi 2.4.11 statistical package.

4. Findings

A statistically significant difference was found in the main factor in the recovery process after the competition routines performed on the ring apparatus ($p<0.001$). In ANOVA repeated measures, no significant difference was found in Rmssd values during 300 seconds in 30-second steps. When analysed with Post Hoc Tukey correction in successive 30-second steps for 300 seconds in ANOVA repeated measures, a significant difference was found in the first 90 seconds R-R values in recovery $p<0.05$ (Table 6).

Table 1: Descriptive Statistics Table of Demographic Data of Gymnasts

	N	Mean	Standart Deviation	Minimum	Maximum
Height (cm)	10	170.3	7.30	159	183
Weight (Kg)	10	67.8	6.70	58	75
Age (year)	10	20.1	3.48	18	28
Sport Age (year)	10	14.5	4.30	10	23
Body Mass Index (kg/m2)	10	23.4	2.13	20.1	27.3

Table 2: Resting Heart Rate (HR), Resting R-R, Resting RMSSD, and Routines Duration (sec) Data of Gymnasts

	N	Mean	Standart Deviation	Minimum	Maximum
Heart Rates (HR)	10	71.3	10.40	58	91
Mean R-R	10	858.6	122.29	658	1043

	N	Mean	Standart Deviation	Minimum	Maximum
Mean Rmssd	10	67.2	26.39	39.4	121
Routine Time (sec)	10	40.1	7.16	30	51

Table 3. Heart Rate Data for 300 second at the start of the routines, at the end of the routines and during recovery.

	N	Mean	Standart Deviation	Minimum	Maximum
Start Routine HR	10	148.7	17.34	120	174
End Of Rou. HR	10	177.1	11.3	157	192
0-30 sec. recovery	10	159.9	11.4	140.5	181
30-60 sec. recovery	10	134.3	13.3	114.5	157
60-90 sec. recovery	10	114.1	17.3	88.6	136
90-120 sec. recovery	10	105.2	18.7	73.4	123
120-150 sec. recovery	10	101.2	15.4	75.2	117
150-180 sec. recovery	10	97.2	16.2	63.4	115
180-210 sec. recovery	10	94.4	14.7	66.4	112
210-240 sec. recovery	10	94.9	12.9	69.3	112
240-270 sec. recovery	10	92.7	12.2	71.2	108
270-300 sec. recovery	10	93.6	12.8	67.6	108

Table 4. Post-Routines Heart Rate R-R Interval Data for 300 Seconds of Recovery

	N	Mean	Standart Deviation	Minimum	Maximum
0-30 sec. recovery	10	377	26.9	332	427
30-60 sec. recovery	10	451	44.3	382	524
60-90 sec. recovery	10	538	86.1	442	677
90-120 sec. recovery	10	590	125.3	487	817

	N	Mean	Standart Deviation	Minimum	Maximum
120-150 sec. recovery	10	607	105.8	512	798
150-180 sec. recovery	10	637	130.3	523	947
180-210 sec. recovery	10	651	114.8	538	903
210-240 sec. recovery	10	644	97.8	536	866
240-270 sec. recovery	10	658	92.0	557	843
270-300 sec. recovery	10	653	102.4	555	888

Table 5. Post- Routines Mean RMSSD Values for 300 Seconds of Recovery

	N	Mean	Standart Deviation	Minimum	Maximum
0-30. Sec Rmssd	10	3.78	1.86	2.60	8.80
30-60. Sec Rmssd	10	6.26	3.79	2.00	11.30
60-90. Sec Rmssd	10	20.74	24.09	2.40	78.80
90-120. Sec Rmssd	10	36.48	52.89	3.70	139.90
120-150. Sec Rmssd	10	35.42	51.44	3.50	149.40
150-180. Sec Rmssd	10	31.88	45.83	3.90	153.10
180-210. Sec Rmssd	10	35.85	56.88	3.40	189.40
210-240. Sec Rmssd	10	29.26	39.32	3.80	133.00
240-270. Sec Rmssd	10	26.59	31.79	3.50	106.90
270-300. Sec Rmssd	10	27.32	31.93	2.70	105.50

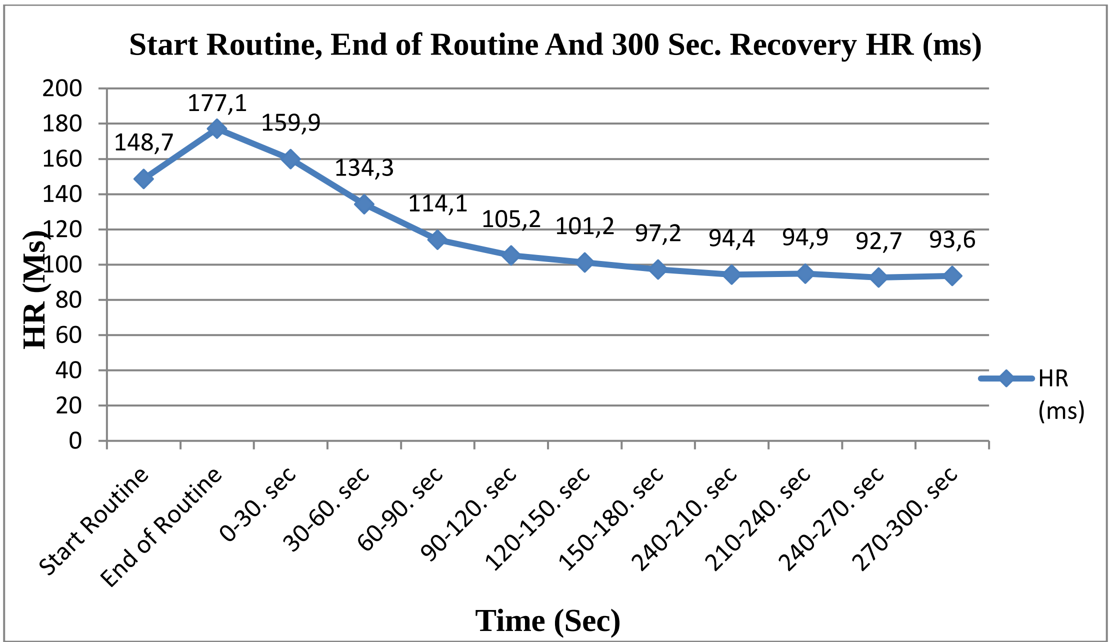
Table 6. ANOVA Repeated Measures Friedman Statistical Data of Post-Routine R-R İnterval Values

Post Hoc Comparisons - RM Factor 1

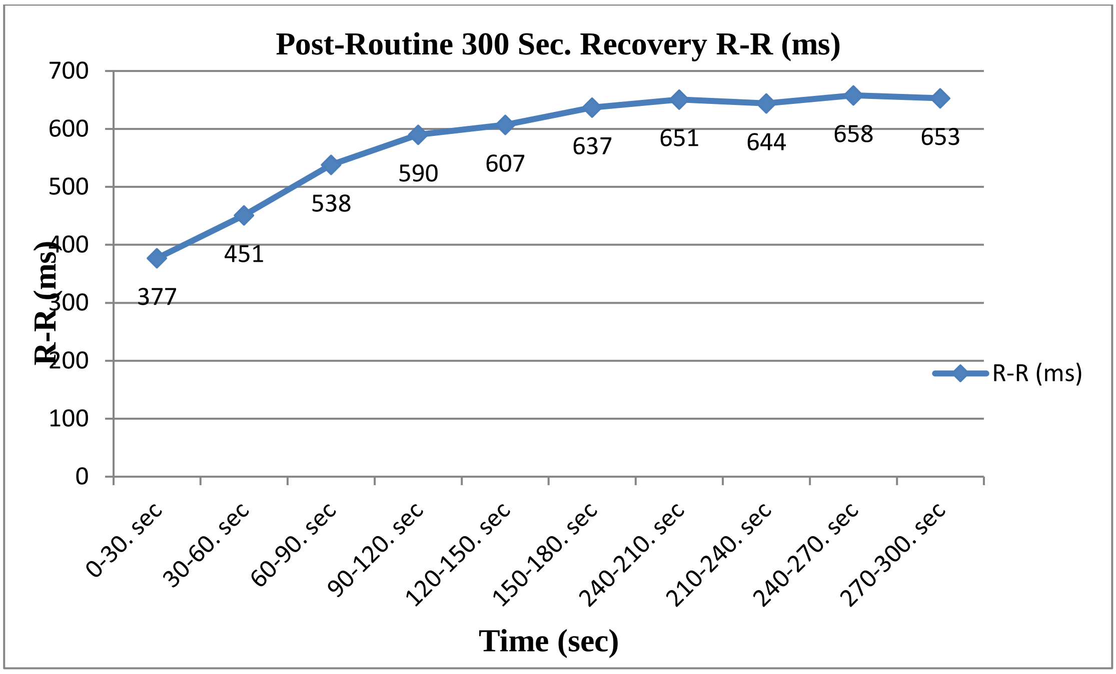
Comparison							
RM Factor 1		RM Factor 1	Mean Difference	SE	df	t	p_{tukey}
30	·	60	-73.70	7.14	9.00	-10.315	< .001
60	·	90	-87.10	16.25	9.00	-5.361	0.009

Post Hoc Comparisons - RM Factor 1

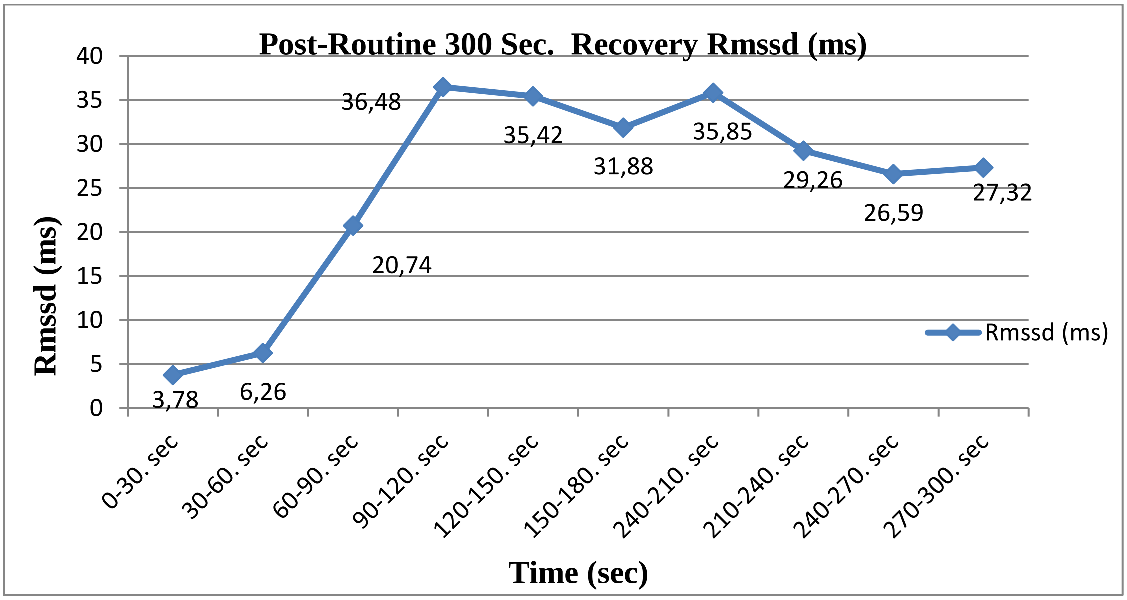
Comparison							
RM Factor 1		**RM Factor 1**	**Mean Difference**	**SE**	**df**	**t**	**p_{tukey}**
90	·	120	-52.60	17.49	9.00	-3.007	0.202
120	·	150	-17.10	6.79	9.00	-2.517	0.366
150	·	180	-29.40	14.79	9.00	-1.988	0.625
180	·	210	-14.40	8.60	9.00	-1.675	0.786
210	·	240	7.40	7.58	9.00	0.976	0.987
240	·	270	-14.20	6.57	9.00	-2.161	0.533
270	·	300	4.70	9.21	9.00	0.510	1.000



Graph 1. Graph of Gymnasts' Routines Start, Routines End, and 300-Second Recovery Heart Rate (HR) Data



Graph 2. Average R-R Values of Gymnasts During 300-Second Recovery Period



Graph 3. Graph of Gymnasts Average RMSSD (ms) Values During 300-Second Recovery Period

5. Discussion

All participants in the study were members of the Turkish national artistic gymnastics team and the junior national team. Among the athletes, two elite Turkish gymnasts had won gold medals at the 2019 and 2023 artistic gymnastics world championships held in recent years, specifically in the rings event. The demographic data of the athletes in the study were height (cm) 170.3 (± 7.30), body weight (kg) 67.8 (±6.7), age (years) 20.1 (±3.48), sporting age (years) 14.5 (±14.5), body mass index 23.4 (±2.13). The gymnasts participating in our study and the sample groups in other studies in the literature have similar demographic characteristics and HRR data (Seemann et al., 2023, Mkaouer et al., 2018, Jemni et al., 2003).

After exercise, heart rate recovery occurs due to the effects of both parts of the autonomic nervous system. The initial heart rate decrease is initiated by parasympathetic reactivation, and the decrease process continues through parasympathetic reactivation and sympathetic withdrawal (Pieront and Stolpman, 2000; Pierpont and Voth, 2004; Borrosen et al., 2008; Imai et al., 1994). Light stimulation can alter heart rate and autonomic balance by increasing sympathetic activity through the central nervous system (Martins et al., 2025). High light levels reduce vagal activity, leading to a decrease in heart rate variability (Martins et al., 2025). Auditory stimuli can cause changes in heart rate by increasing the sympathetic response via the brainstem and reticular activating system (Silva et al., 2024). Sound stimuli such as noise and music can significantly affect both time and frequency domain HRV parameters (Silva et al., 2024). Eye and ear isolation, on the other hand, stabilizes autonomic nervous system activation by reducing external sensory stimuli and increases the reliability of the measurement (Liu et al., 2021; Ahmed et al., 2022). The acute heart rate recovery process is generally examined in two phases; the rapid phase represents a phase covering the first minute and representing the parasympathetic reactivation phase (Fecchio et al., 2019; Weippert et al., 2013). At the same time, the movements in the applied competition series, involving maximum intensity isometric and dynamic contractions throughout the entire body and excessive load only on the upper extremities, may lead to increased metabolite formation as a result of high-intensity anaerobic metabolic activity and mechanical occlusion.

Several studies have suggested that the accumulation of metabolites within skeletal muscle may increase the afferent firing frequency of muscle chemoreceptors, thereby enhancing sympathetic activation on the cardiac excitation–conduction system through the metabaroreflex mechanism. Similarly, it has been reported that metabolite buildup in active skeletal muscles may stimulate afferent nerve endings and chemoreceptors within the carotid body, contributing to an augmented cardiovascular response. Within this framework, it is proposed that these physiological responses may be associated with the metabaroreflex mechanism. (Shaffer et al., 2014; Toprakoğlu, 2021). Epinephrine released into the systemic circulation during exercise may cause an increase in sympathetic stimulation. This can suppress cardiac parasympathetic reactivation. The metabolites produced in the muscles during the suppressed parasympathetic reactivation activity may also require a longer period for the metabolites to pass into the blood after the series (Hung et al., 2020).

A recently published long-term study observed both an increase in muscle strength and biventricular cardiac remodeling associated with high-intensity resistance training (Pamart et al., 2025). Additionally, a recent review study emphasizes that the “athlete's heart” phenomenon involves structural and functional cardiac adaptations not only in endurance sports but also in strength/resistance sports (Maxwell, 2025). It has been shown that resistance-focused sports lead to adaptations in cardiac structure, such as increased ventricular wall thickness and heart mass (Fagard, 1996; Pluim et al., 2000). However, there is no specific study in the literature examining the direct relationship between this adaptation and ‘masculinity and hypertrophy with high heart rate’. Therefore, this relationship has not been confirmed by current evidence and may be presented as a hypothetical suggestion in the discussion.

The primary reason for conducting post-exercise measurements in the supine position is that this posture is one in which parasympathetic activity returns most rapidly and sympathetic load is lowest; this allows the actual effects of the recovery process on the autonomic nervous system to be observed more clearly (Shaffer & Meehan, 2020). Keeping the athlete's eyes and ears closed during measurement aims to prevent external stimuli such as light and sound from increasing sympathetic activation through the central nervous system, which could lead to deterioration in heart rate and HRV values; thus, the recovery response is evaluated free from external stimuli (Laborde et al., 2020).

Analyzing data divided into 30-second segments reveals that changes in the autonomic nervous system occur very rapidly during the early recovery period after exercise. Therefore, it is thought that short time windows will enable a more detailed examination of the temporal patterns of recovery by increasing temporal resolution. This approach is consistent with the segment-based methodology recommended for short-term HRV analysis and increases the power and sensitivity of statistical analysis (Perrotta et al., 2020; Cramer et al., 2021).

In line with this information, it is thought that sympathetic withdrawal is active during the first 90 seconds, while parasympathetic activation increases more significantly in the subsequent process. The rapid decrease in heart rate observed during the first 120 seconds after the series and the section where parasympathetic activation in Rmssd values is thought to be more dominant until the 120th second show simultaneous alignment. (Graph 1, Graph 3) Similarly, the rapid increase in RR values during the first 120 seconds suggests that parasympathetic activation is effective in short-term autonomic recovery. Although there is a statistically significant difference in R-R values (Table 6.), the absence of a statistical difference in Rmssd values is thought to be related to the low number of participants in the study. The intensity of the movements performed during the three-minute free warm-up before the series, changes in emotional state such as excitement, and preparation for competition performance may have contributed to the increase in heart rate values before the series.

During the rings routines, the Polar H10 chest strap consistently exhibited marked distortions in the heart rate signal immediately upon the initiation of the series, with measurements returning to normal as soon as the routine was completed. Because this pattern appeared similarly across all participants, it is plausible that the intense and high-tension muscle contractions throughout the routine generated substantial mechanical and electrical interference in the chest area, temporarily challenging the device’s capacity to distinguish the cardiac signal. Consequently, the device may have been unable to sufficiently differentiate the true cardiac activity from contraction-related artifacts during periods of high muscular tension, resulting in transient measurement disturbances. This finding suggests that the device’s technology may have inherent limitations in capturing heart rate signals without error under extreme isometric loading conditions. As this issue also recurred during pre-tests, it was considered a systematic measurement artifact specific to the rings apparatus. Similarly, in the study by Jemni et al. (2000), a note stating “artefacts found in data” appears under the heart rate graph for the ring device, and it is reported that HR measurement during the ring exercise failed due to artifacts. As a result of a similar situation in our study, the measurements during the series could not be statistically evaluated. Therefore, it is thought that chest strap-based HR measurements on the ring device may be limited, and it may be useful to evaluate different sensor technologies or alternative measurement methods that provide a more stable signal in the future. Due to the high physiological similarity between the force movements in the ring apparatus and resistance exercises, it is thought that the increase in parasympathetic activity during post-series recovery may be the main cause.

7. Conclusion

As a result of the study, it was observed that in the average 40.1-second competition series measurements performed on the artistic gymnastics rings apparatus, gymnasts reached 60% of their maximum HRR before the series and 82% of their maximum HRR at the end of the series. The rules and nature of the rings apparatus, which requires maximum isometric force exerted by the upper body extremity muscles, suggest that this discipline is suitable for resistance exercise modeling. In this discipline, where maximum strength is dominant, the observation of a physiological effect equivalent to 82% of the maximum heart rate after the series suggests that the anaerobic energy system is dominant. However, during the recovery processes after the series, rapid recovery occurred in the first 120 seconds, followed by slow recovery in the subsequent 180 seconds. This is thought to be due to the fact that more time is needed to remove the metabolites formed in the muscles as a result of maximum intensity isometric muscle contractions.

In light of the above information, it is thought that aerobic capacity may be low due to high resting HR. Considering the generally high resting HR of artistic gymnasts, their relatively developed muscle structure, body composition, and the load that muscle mass places on the heart and circulatory system, it is plausible to argue in the literature that this physiological load may affect the competitor-specific loading and recovery dynamics of heart rate, especially after training and exercise. The movements technically performed on the apparatus have a similar physiology to resistance exercises. Developing muscular endurance and repetition-based strength in training programs can positively affect the physiological processes of the 10 movements performed on the apparatus during competition and the aerobic capacity effective during recovery. Performing isometric strength holds at maximum levels with coach support or various assistive equipment can allow for more repetitions by reducing the maximum intensity applied to the muscle. In this case, the increase in training volume can enhance muscular endurance parameters and work capacity.

Furthermore, when examining the recovery profiles of gymnasts, it is observed that full rest periods are required after performing maximum-intensity isometric contractions. Implementing long rest periods after performance is thought to improve performance quality and significantly reduce performance decline due to fatigue and the risk of injury.

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