RECOVERY PROCESSES IN RHYTHMIC AND ACROBATICS GYMNASTS

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ABSTRACT
Recovery in gymnastics is a subject of in-depth research. However, in the past, endurance was considered to be a minor factor in sports achievement in gymnastics disciplines. Gymnastics falls under the anaerobic regime of work during the competitive routines. At the same time, in the context of overtraining prevention, it is important to understand how the cardiovascular system responds following a training load and how the body's physiological systems adapt and recover during the post-exercise period. The aim of this study was to examine the recovery process in rhythmic and acrobatic gymnastics following a 2-minute submaximal test. Twenty-four female (12 rhythmic and 12 acrobatics – mean age of 15,5 (±1,8)) elite gymnasts (part of the Bulgarian National Team) were tested. The study was conducted in two stages: Stage 1, during the preparation period, and Stage 2, during the competitive period. A 2-minute Shuttle test was performed. The indicators measured were heart rate (HR) and blood lactate concentration (La). At the end of the load, rhythmic gymnasts reached HR values of 190 bpm during the preparatory period and 183 bpm during the competitive period, while blood lactate concentrations peaked at 11 mmol/L and 8 mmol/L, respectively. Acrobatic gymnasts exhibited HR values of 190 bpm and 188 bpm across the two periods, with corresponding La levels of 14 mmol/L and 11 mmol/L. Based on the calculated modified tau parameter and blood La levels, it can be concluded that the recovery process in acrobatic and rhythmic gymnastics during the preparation period was comparable to the competition load intensity and could be effectively monitored.

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INTRODUCTION

Gymnastics, in all its variations, encompasses a vast array of technical moves and complexities, both in terms of technical aspects and physiological demands. FIG (Fédération Internationale de Gymnastique) regulates all gymnastics disciplines to ensure similar conditions and structure, including the duration and the way of judging the routines (Code of Points – Rhythmic 2023 & Acrobatics Gymnastics 2023). In gymnastics disciplines, efforts have been made to develop specific endurance tests, including both field-based and laboratory assessments (Heller et al., 1998; Gateva, Tarnichkova, & Ivanov, 2013; Alves et al., 2015; Mkaouer et al., 2023). Comparing the training load across gymnastics disciplines is challenging, primarily due to the limited literature available on acrobatic gymnastics, whereas rhythmic gymnastics has been studied. Buckner, Bacon, and Bishop (2017) reported in a study on female artistic gymnasts that while most athletes required up to 72 hours for full recovery after a routine, some recovered within 48 hours. These insights highlight the importance of individualized recovery timelines and can help coaches optimize training schedules for peak performance. Heart rate variability (HRV), specifically the difference in mean RR intervals (mean R-wave to R-wave interval) or SD1 between training and reference days, may be a valuable tool for monitoring training load and psychophysiological status in young male elite gymnasts (Sartor et al., 2013). More studies have investigated training load and recovery across an entire season rather than focusing on short-term recovery during individual training sessions (Debien, 2020). In rhythmic gymnastics, although this approach may have limitations for effectively managing training load, coaches' perception remains the most commonly used method to monitor load, recovery, fatigue, and performance (Debien, 2022). This finding was revealed through online surveys conducted with over one hundred professionals and gymnasts involved in rhythmic gymnastics training worldwide. Understanding how the cardiovascular system responds to training load, as well as how various physiological systems react during the recovery process, is essential for optimizing athletic performance and preventing overtraining. Focusing on recovery time between exercises during training has been done by Buckner et al. (2017). "If the gymnast is not fully recovered, then they will not be able to perform at the highest intensity". Consequently, it is essential for researchers to define adequate recovery periods to better support coaches and gymnasts in optimizing training and performance.

Aim and Objectives

The ***aim*** of this study was to examine the recovery process in rhythmic and acrobatic gymnastics following a 2-minute submaximal test. Building on previous work that implemented a new field-based endurance test in selected gymnastics disciplines, this study focused on monitoring the recovery period following the test. Additionally, the study aimed to develop a unified recovery protocol applicable to both rhythmic and acrobatic gymnastics.

METHODOLOGY

Participants

Twenty-four female elite gymnasts (12 rhythmic and 12 acrobatics – mean age of 15.5 ± 1.8) from the Bulgarian National Teams in both disciplines were tested. The acrobat gymnasts trained 24(±2) h and the rhythmic gymnasts 33 (±2) h per week. The testing was conducted twice during the macrocycle: once during the preparation period and again during the competitive period. This study was conducted in accordance with the Declaration of Helsinki for Human Research (WMA, 2008), and an institutional ethics approval was obtained from the National Sports Academy, Sofia, Bulgaria.

Protocol

A 2-minute Shuttle run test (Gateva, Tarnichkova, & Ivanov, 2013) was performed with a set distance of 10 m within two lines. Each time, the gymnast must run at maximal speed and touch the outside of the lines. The covered distance in meters (with an accuracy of up to 0.5 m) is measured for 2 minutes. Athletes start in pairs.

The indicators measured were *HR and blood La*. The heart rate was recorded every 15 seconds by POLAR RCX3. The recording started at rest and continued until 9 minutes post-exercise (active recovery period for the first three minutes, followed by more than six minutes of passive recovery). A drop of blood sample was taken from the fingertip to assess the average peak blood lactate concentration using an Accutrend Plus Roche. Lactate was taken before and at the 3rd, 5th, and 9th minutes during the recovery period. A ten-minute warm-up preceded the start of the tests.

Procedure for determining the physiological indicators EPOC and TAU by analyzing pulse rate and average speed during the field interval test (methodology is intended for cases where direct measurement using a gas analyzer is not used):

EPOC was indirectly estimated using heart rate (HR) data and average running speed (V), based on the model proposed by Léger and Mercier (1980):

$$EPOC=a\cdot HR+b\cdot V+cEPOC=a\cdot HR+b\cdot V+c \qquad (1)$$

This is a close linear/nonlinear model, where HR represents heart rate; V – average speed during the shuttle test (m/s); a and b are the coefficients describing the sensitivity of EPOC to HR and V, respectively. The parameter c is the correction coefficient that compensates for the baseline oxygen consumption (or baseline EPOC) at rest. It represents the "zero point" of the model, corresponding to the EPOC value when both HR and V approach resting levels (mathematically, if HR = 0 and V = 0, then EPOC = c). In the original work by Leger and Mercier (1980) and later adaptation (Gore & Withers, 1990; LaForgia et al., 2006), the values of a, b, and c were determined through multiple linear regression based on experimentally measured EPOC values obtained via gas analysis at different exercise intensities. The resulting EPOC value is then multiplied by body mass (kg) to express the result in milliliters (ml).

To calculate TAU, an exponential modeling of the decrease in heart rate (HR) over time is used:

$$HR(t) = HR\_rest + (HR\_peak - HR\_rest) * \exp(-t / \tau) \qquad (2)$$

Where: HR(t) – heart rate at time t; HR_rest – resting heart rate (at the end of recovery); HR_peak – maximum heart rate (at the end of exercise); τ – TAU (time constant); t – time in the recovery

period (Imai et al., 1994). TAU is calculated individually for each athlete by nonlinear regression on the 9-minute recovery period (taken every 15 seconds).
Anthropometric indicators, such as height, weight, body fat, active body mass, and muscle mass, were recorded using InBody 230 (Korea) Body Composition Analysers.

Statistical analysis
Statistical analysis included descriptive statistics. A Student's paired t-test was applied to find differences between all parameters within the groups, while a *Student's independent t-test* was used to compare the sports. The level of significance of $p \leq .05$ was adopted in all cases.

RESULTS
In Table 1 are presented the mean age and the main anthropometric characteristics of the tested individuals in the preparatory and competitive periods.

Table 1. *Anthropometric characteristics of Acrobatic and Rhythmic gymnasts (both periods)*

	Age (years) *Mean ± SD*	Hight (cm) *Mean ± SD*	Weight (kg) *Mean ± SD*	Body Fat (%) *Mean ± SD*	Activ Body Mass (kg) *Mean ± SD*	Muscle Mass (%) *Mean ± SD*
AG PP*	15.5±1.8	158.8±7.4	47.7±8.3	14.7±4.6	40.4±5.6	41.7±2
AG CP**	15.5±1.8	159.0±7.1	48.5±8.0	14.5±4.0	41.2±5.5^	41.8±2.1
RG PP*	15.6±2.2	160.3±8.4	46.7±8.1	13.6±5.0	40.1±5.9	41.1±1.9
RG CP**	15.6±2.2	161.7±8.0	48.5±8.0	15.5±5.1^	40.8±5.7	40.9±1.9

Notes: AG – acrobatic gymnastics; RG – rhythmic gymnastics; *PP – preparatory period; **CP – competitive period
^p < .05 significant difference between the periods

An analysis of the anthropometric characteristics revealed that rhythmic gymnasts showed an increase in body fat percentage from the preparatory to the competitive period. In contrast, acrobatic gymnasts demonstrated an improvement in active body mass during the competitive period (statistically significant).

Table 2. *Descriptive Statistics of the 2-Minute Shuttle Run Test in Rhythmic Gymnastics*

	Distance (m)	Average Speed (m/sec)	HR-max	TMHR	% of reached TMHR	La (mmol/L)	Recovery time (min) to aerobic threshold at 120 bpm	tau (min)	EPOC (mL/kg)
Preparatory Period									
Mean **± *SD***	323.3 ± 15	2.7 ± 0.1	190.9 ± 6.2	204.4 ± 1.4	93.4 ± 2.8	10.8 ± 1.8	4.1 ± 2.1	1.9 ± 0.67	66.4 ± 15.3
V%	4.64	4.64	3.24	0.7	3.0	16.7	51.9	36.0	23.1
R	50.0	0.4	17.0	5.0	7.8	5.1	7.7	2.2	48.2
Min	300.0	2.5	182.0	202.0	89.2	8.3	1.3	0.9	38.3
Max	350.0	2.9	199.0	207.0	97.0	13.4	9.0	3.1	86.5
Competitive Period									
Mean **± *SD***	310.8* ± 11.4	2.6* ± 0.1	183.6** ± 7.4	204.4 ± 1.4	89.8** ± 3.4	8.2** ± 2.1	2.3* ± 0.9	1.5* ± 0.7	61.7* ± 14.8
V%	3.67	3.67	4.01	0.7	3.7	25.3	38.6	43.5	24.0
R	40.0	0.3	24.0	5.0	11.9	6.6	3.0	2.3	52.2
Min	300.0	2.5	169.0	202.0	83.7	5.6	0.5	0.7	38.5
Max	340.0	2.8	193.0	207.0	95.5	12.2	3.5	3.0	90.8

*Notes: TMHR – theoretical maximal heart rate; *p < .05 significant difference between the periods; **p < .01 significant difference between the periods*

The average running speed during a two-minute test ranged from 2.6 to 2.7 m/s (±0.1) for rhythmic gymnasts and was significantly higher for acrobatic gymnasts, at 2.8 to 2.9 m/s (±0.2). At the end of the load, rhythmic gymnasts reached heart rate (HR) values of 190 bpm during the preparatory period and 183 bpm during the competitive period, while blood lactate concentrations peaked at 11 mmol/L and 8 mmol/L, respectively (Table 2). Acrobatic gymnasts exhibited HR values of 190 bpm and 188 bpm across the two periods, with corresponding lactate levels of 14 mmol/L and 11 mmol/L (Table 3). Both HR and lactate values showed a decline during the competitive period for RG, indicating a positive adaptation. In acrobatic gymnasts, only blood lactate levels showed a statistically significant difference. The results showed more significant differences between the two periods in rhythmic gymnasts. Nearly all parameters exhibited changes, in contrast to acrobatic gymnasts, where differences were observed only in blood lactate levels and the two theoretically calculated parameters: tau and EPOC.

Table 3. *Descriptive statistics of the 2-minute Shuttle Run Test in Acrobatics Gymnastics*

	Distance (*m*)	**Average Speed (m/sec)**	**HR-max**	**TMHR**	**% of reached TMHR**	**La (mmol/L)**	**Recovery time (min) to aerobic threshold at 120 bpm**	**tau (min)**	EPOC (mL/kg)
				Preparatory Period					
Mean ± SD	342.9 ± 19.7	2.9 ± 0.2	189.2 ± 5.5	204.5 ± 1.8	92.5 ± 2.9	14.2 ± 3.1	4.6 ± 2.3	2.4 ± 0.8	70,0±12.0
V%	5.8	5.8	3.1	0.9	3.2	21.9	50.2	34.7	17.1
R	65.0	0.5	17.0	5.0	8.7	10.2	6.9	3.0	45.1
Min	305.0	2.5	181.0	202.0	87.4	7.3	2.2	1.4	47.4
Max	370.0	3.1	198.0	207.0	96.1	17.5	9.0	4.4	92.5
				Competitive Period					
Mean ± SD	334.2 ± 28.7	2.8 ± 0.2	187.8 ± 5.9	204.5 ± 1.8	91.8 ± 3.1	10.9** ± 2.5	3.8 ± 2.6	1.6* ± 0.8	66.7** ± 11.4
V%	8.6	8.6	3.2	0.9	3.4	22.7	68.6	50.0	17.1
R	95.0	0.8	20.0	5.0	10.7	8.5	8.0	2.7	44.4
Min	285.0	2.4	174.0	202.0	85.3	6.0	1.0	1.0	44.6
Max	380.0	3.2	194.0	207.0	96.0	14.5	9.0	3.8	89.0

*Notes: TMHR – theoretical maximal heart rate; *p < .05 significant difference between the periods; **p < .01 significant difference between the periods*

As shown in Table 3, acrobatic gymnasts exhibit higher values during the nine-minute recovery period in both the preparatory and the competitive phases. Specifically, during the preparatory period, their recovery values remain noticeably higher up to the fourth minute of recovery.

Acrobatic gymnasts performed better in the test, as indicated by the greater distance covered, which showed a statistically significant difference. Recovery time during the competitive period resulted in accelerated recovery and lower τ-values in both disciplines. Rhythmic gymnastics is characterized by the fastest recovery time (2.3 minutes), suggesting more efficient autonomic regulation and greater cardiac adaptation. Acrobatics gymnasts showed significantly higher lactate values (up to 14.2 mol/L), particularly during the preparatory period, indicating a high glycolytic load. In rhythmic gymnastics, lactate levels are approximately 25% lower, indicating more moderate anaerobic involvement. EPOC is higher in acrobatic gymnastics, reflecting greater energy expenditure and an increased need for recovery. EPOC decreases during the competitive period in both disciplines, but remains lower in rhythmic gymnastics.

DISCUSSION

Some studies (Debien et al., 2020) describe the training load (volume and intensity) of high-level rhythmic gymnasts during the competitive period and its association with injury types, but they do not provide tools to monitor the internal responses to the applied load. Others (Buckner et al., 2017) have explored ways to control this process, but in artistic gymnastics. Few studies have examined the physiological processes involved in rhythmic and acrobatic gymnastics routines (Gateva, 2015, 2019; Ivanov, 2018, 2020, 2022). Therefore, research in these two gymnastics disciplines remains limited.

Running is not a typical motor activity in gymnastics. Nevertheless, several studies have incorporated running-based field tests to evaluate different components of gymnasts' physical fitness. Fay, Held, Rappelt, Rohleder, and Donath (2024) examined the validity and reliability of a 12 m shuttle run test performed on a gymnastics floor and tailored for young gymnasts. Galukhin (2021) employed a 10×5 m shuttle run test; however, no specific results were reported for this measure. Similarly, Seredyński and Polak (2015) utilized a 4×10 m shuttle run test. However, these findings are not directly comparable to the results of the current study, as the test employed here was designed to assess discipline-specific endurance in gymnastics, considering both exercise duration and intensity. Despite its non-specificity, this type of cyclic activity imposes considerable stress on the athlete's body. However, the total distance covered during the test decreased in the competitive period, by 7 meters in acrobatic gymnasts (not statistically significant for AG) and 13 meters in rhythmic gymnasts (statistically significant for RG). Several factors may have contributed to this reduction: not setting effort as a treadmill test; 2 – gymnasts experienced the initial testing as extremely demanding; 3 – have not pushed themselves (not all). Therefore, the recovery defines a better training state, and tau has significantly better values. For rhythmic gymnasts, a two-minute (2.3 min) recovery period during the competitive period was sufficient to return HR to below the aerobic threshold of 120 bpm, compared to the preparatory period, where the time to reach that zone was 4.1 min. In previous publications, Gateva (2012) showed that a 4-minute recovery after a routine in real conditions is sufficient for gymnasts to restore their respiratory and cardiovascular systems to baseline values, but not their metabolic indicators. Athlete monitoring in ACRO is often biomechanical in nature, focusing on strength and force production rather than internal physiological markers. However, previous research by Ivanov (2018, 2020) showed that 2:39 min and 2:49 min were required to reach 120 bpm after performing the acrobatic and modified routines, respectively. The increased volume and intensity of mechanical tasks in acrobatics – such as partner lifts, throws, and catches – suggest a higher overall load. During the competitive period, rhythmic gymnastics demonstrates better parameters for rapid recovery, suggesting the potential for shorter intervals between training loads. Acrobatic gymnastics during the preparatory period requires longer recovery due to the high anaerobic load. Rhythmic gymnastics during the competitive period allows shorter intervals between sets (~2.5 min). This is especially important when planning interval training, double loads, or multiple performances during intensive training sessions.

At the same time, three base acrobatic gymnasts were injured and had to restart the season late. As a result, they were likely not at the same level of peak performance as the other subjects during the competitive period. Another reason for significantly higher values of HR for acrobatic gymnasts can be speculated to be that their routine is exceptionally high in strength-endurance demands but has fewer dynamic movements compared to rhythmic discipline. Thus, the nonspecific running at high speed for 2 minutes can explain the longer recovery of the HR, especially in the preparatory period.

CONCLUSION

Based on the calculated modified tau parameter and blood lactate levels, it can be concluded that the recovery process in acrobatic and rhythmic gymnastics following a load comparable to competition intensity can be effectively monitored. This approach may be applied in practice to track and evaluate recovery status in gymnasts. The recovery time required following a high-intensity load in rhythmic gymnastics is approximately 4 minutes during the preparatory period and 2.15 minutes during the competitive period. In acrobatic gymnastics, recovery durations are more extended, averaging 5 minutes during the preparatory period and approximately 4 minutes during the competitive period before re-exposure to similar intensity loads.

LIMITATIONS

It should be noted that field-based predictive models rely heavily on the quality of input data; therefore, estimates of EPOC derived without direct gas analysis can deviate by approximately ±10–15%.

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