

CARDIORESPIRATORY ADAPTATION TO DIFFERENT TRAINING LOADS IN FUTURE WATER RESCUE PROFESSIONALS

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***Abstract:** Water rescue is a high-responsibility activity that demands excellent physical conditioning and the ability to respond effectively in dynamic and challenging environments. Physiological adaptation to exertion and efficient recovery are crucial for maintaining operational performance and preventing overtraining among lifeguard trainees. This study aims to analyse the physiological responses of participants undergoing lifeguard training under varying training loads. Using waterproof wearable monitoring devices, key physiological parameters, such as heart rate (HR) and heart rate variability (HRV), are continuously tracked. At the end of the training cycle, a structured survey assesses subjective perceptions of fatigue, vitality, and recovery. Comparative analysis of these data enables the evaluation of training intensity and individual adaptive capacity. The findings aim to support the optimisation of training programmes through a personalised approach based on the physiological profiles and individual needs of future water rescue professionals.*

***Keywords:** water rescue, adaptation, heart rate (HR), heart rate variability (HRV)*

INTRODUCTION

The profession of a water rescuer requires excellent physical endurance, mental resilience, and the ability to respond quickly in dynamic conditions. The training process involves intensive, functionally diverse, and simulation-based loads that place significant physiological stress on the body. Therefore, monitoring the adaptive responses to training load becomes crucial for maintaining optimal performance, preventing overtraining, and preserving the health of the trainees.

Physiological adaptation to physical effort is the result of a complex interaction between the cardiorespiratory system, autonomic nervous regulation, and muscular-energy responses. In a water environment - where factors such as hypothermia, hydrostatic pressure, and restricted

mobility further increase the load - the need for precise monitoring becomes even more pressing. In this context, indicators such as heart rate (HR) and heart rate variability (HRV) are established as reliable biomarkers for assessing current functional status and recovery capacity.

This study is conducted among lifeguard trainees subjected to different training loads in a real educational setting. Through a combined approach including objective physiological measurements and subjective self-assessments of fatigue, vitality, and recovery, the aim is to construct a comprehensive picture of the trainees' adaptive capacity. The data obtained serves as a basis for understanding individual differences in response to training loads and for developing personalized strategies for structuring the training process. Such an approach has the potential to enhance training effectiveness, minimize the risk of overload, and ensure greater safety and professional readiness in water rescue practice.

MAIN TEXT

Between March and April 2025, trainees undergoing water rescue training were studied. The analysis included monitoring cardiovascular and oxygen-transport responses under real training conditions. A multi-methodological approach was applied, combining physiological measurements and a questionnaire survey, allowing a comprehensive understanding of individual bodily responses to training.

Aim and Objectives

The aim of the present study is to analyze the morphofunctional adaptive responses of water rescue trainees under different training loads, with an emphasis on creating conditions for effective recovery, reducing the risk of functional overload, and optimizing the training process.

Materials and Methods

The study was conducted between March and April 2025 among trainees enrolled in a certified water rescue training program accredited by the Bulgarian Red Cross. A total of 9 participants of both sexes, aged between 17 and 19 years, with different initial levels of physical fitness, voluntarily took part. All participants were informed in advance about the aims and methods of the study and signed an informed consent form in accordance with ethical standards. Each participant provided prior information on their health status and physical fitness.

To meet the study's objectives, a multi-methodological approach was employed, combining:

- Physiological measurements using waterproof wearable devices enabling continuous recording of heart rate (HR) and heart rate variability (HRV);
- A standardized questionnaire assessing self-reported fatigue, vitality, and recovery, completed after the training session.

All measurements were conducted in real training conditions, and a training log was maintained simultaneously.

Results

The data from the study are presented in two main tables: individual physiological parameters per participant (Table 1), and heart rate response by type of exercise (Table 2). Heart rate (HR), heart rate variability (HRV), body composition, and energy expenditure values are systematized for each participant. Specific pulse and variability responses during each training exercise were also recorded, including: warm-up, underwater swimming, interval ladder, dummy retrieval, stamping (trampovka), and cooldown.

There was variation in average and maximum HR among participants—from 102.4 bpm to 140.7 bpm average, and from 148 bpm to 190 bpm maximum. HRV ranged from 16.5 to 22.0 ms, with the lowest values observed during high-intensity exercises.

Table 1. Individual Physiological Indicators by Participant

Participant	Sex	Avg. HR (bpm)	Max HR (bpm)	HRV (SD, ms)	Distance Covered (m)	Calories Burned	Fat (%)	BMI
№1	♂	109.0	154	17.3	1500	342	22.8	25.0
№2	♂	121.4	164	22.0	2100	468	26.6	28.0
№3	♂	140.7	190	21.0	2325	570	41.5	43.5
№4	♀	111.4	161	16.5	2400	567	26.9	20.1
№5	♂	111.0	148	17.2	1950	495	24.3	24.4
№6	♀	133.9	176	16.7	3101	1272	33.5	23.5
№7	♂	127.4	179	21.6	1500	333	25.5	26.0
№8	♂	102.4	176	21.6	1800	468	22.4	23.4
№9	♂	107.7	159	20.7	1575	372	18.4	23.3

Table 2. Heart Rate Response by Type of Exercise

Exercise	Intensity	Avg. HR (bpm)	HRV After Exercise	Note
Warm-up	Low	108–115	Moderate	Stable starting point for most participants
Underwater (20 m)	Moderate	120–132	HRV decreased	Increased effort due to breath-holding
Ladder (intervals)	High	130–145	Significant HRV drop	Cumulative load
Dummy retrieval (20 m)	High	140–165	Low HRV	High effort and coordination
Stamping (1 min)	Very high	145–175	Lowest HRV	Time of peak sympathetic activation
Cooldown	Low	100–115	HRV increases	Good recovery among well-adapted participants

Most participants rated the physical exertion as moderate, with an average score of approximately 2.2 on the applied 5-point scale. This corresponds with the reported moderate levels of fatigue observed on the day following the training.

More than 80% of the trainees indicated that they had sufficient energy for daily activities or felt invigorated. Nevertheless, only two participants (№ 5 and №6) described themselves as fully recovered, while the remaining participants reported partial recovery.

Objective physiological indicators also showed variations that corresponded to the subjective assessments. Participant No. 3, who exhibited the highest heart rate and the lowest HRV values, reported the greatest fatigue and the lowest readiness for a new training session. In contrast, Participants № 4 and №6, who demonstrated stable physiological responses, also reported a high degree of satisfaction and vitality.

Discussion

❖ Based on Heart Rate and Frequency

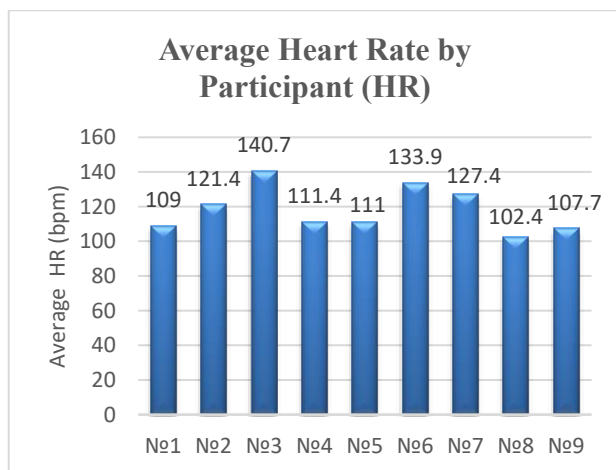
Participant №3 exhibited the highest heart rate and frequency values and also showed the highest body mass index (BMI = 43.5) and fat percentage (41.5%). These results indicate limited cardiac efficiency and a need for careful structuring of training loads. His pulse remained elevated even during moderate-intensity exercises, and HRV did not recover effectively after cooldown, signaling low autonomic regulation.

In contrast, Participant №4 showed a stable and low average pulse (111.4 bpm) and low HRV (16.5 ms), indicating efficient cardiac adaptation under load. Despite an intensive training

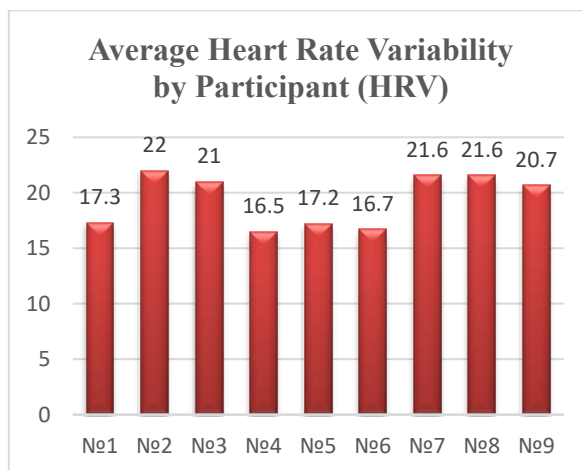
program, she maintained a stable physiological response. Her profile may serve as a model of effective adaptation.

Participant №6, who began training earlier than the others and showed high motivation, demonstrated strong cardiac engagement (average HR 133.9 bpm) during the longest swimming distance (3101 m) and highest energy expenditure (1272 kcal). Despite these high values, her HRV remained stable (16.7 ms), highlighting good capacity for adaptation to prolonged and intense effort. This profile shows that experienced participants can handle high loads without destabilizing cardiac function.

Participants №7 and №8 exhibited high heart rate variability (HRV > 21 ms) without significant increases in heart rate, possibly indicating uneven effort or pacing fluctuations, potentially related to technical instability or lower fitness levels.

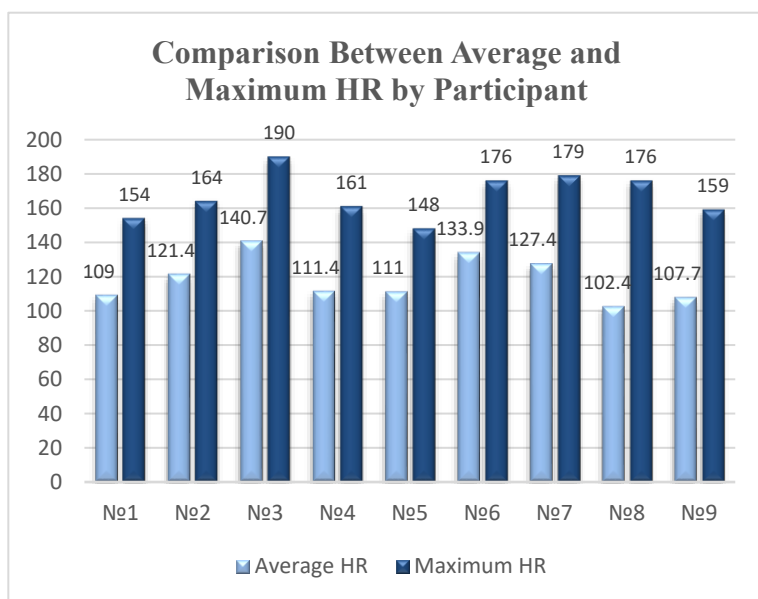


Graph 1. Average Heart Rate by Participant (HR)



Graph 2. Average Heart Rate Variability by Participant (HRV)

❖ Based on Average and Maximum HR



Participant №3 demonstrated the highest values in both indicators, signifying high cardiovascular stress and limited adaptive capacity.

In contrast, participants such as #8 and №9 showed lower HR values and smaller differences between average and maximum HR, reflecting more efficient load regulation.

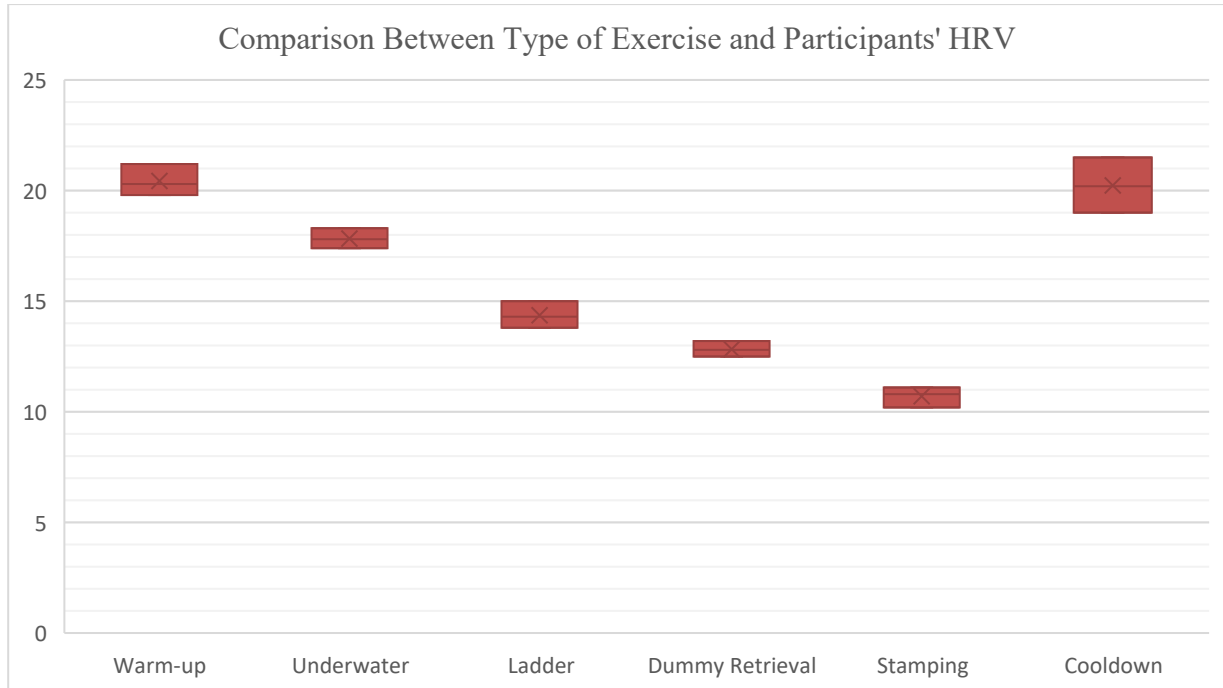
Graph 3. Comparison Between Average and Maximum Heart Rate (HR) by Participant

❖ Based on Exercise Type

Lowest HR values were observed during warm-up and cooldown, whereas exercises with high complexity and intensity – time-based ladder, dummy retrieval, and stamping—resulted in distinct HR increases. HRV values declined most sharply after stamping, reflecting a peak in

sympathetic activity. These results are consistent with the expected physiological demands of short, intense efforts.

Exercise phase analysis showed that peak intensity exercises, such as stamping and retrieval, caused the lowest HRV and highest HR values, while cooldown facilitated rapid recovery among trained participants. The ladder exercise, being a progressive interval load, functioned as a sensitive stress test for the cardiovascular system.



Graph 4. Comparison Between Type of Physical Exercise and Participants' Heart Rate Variability (HRV)

❖ Subjective Data Analysis

Following the questionnaire, Participants #5 and #6 reported the highest self-assessments for recovery, vitality, and readiness for a new workout, perceiving the workload as light and expressing full satisfaction. This indicates good adaptation and effective recovery.

Participant #3 reported a discrepancy between perceived effort (moderate) and low readiness, matching the physiological data and highlighting the need for more precise load calibration in the future.

The remaining participants gave moderate evaluations—reporting moderate fatigue, partial recovery, and good motivation to continue. This suggests that, while recovery was not complete, the participants felt functionally capable of resuming activity.

The consistency between physiological and subjective indicators confirms the effectiveness of the combined approach in monitoring adaptation to training loads and readiness for subsequent sessions.

CONCLUSIONS

Based on the analysis, the following key conclusions can be drawn:

- The physiological response to physical exertion among water rescue trainees shows significant variability, influenced by individual factors such as sex, body composition, fitness level, and adaptive capacity.
- The results confirm the need for a personalized approach in planning and structuring training regimes tailored to the specific physiological characteristics of participants.

- Combining wearable monitoring technologies with subjective self-assessment represents a valid and practically applicable method for evaluating adaptation and detecting early signs of functional overload in field settings.
- Integrating regular physiological measurements into standard training protocols could significantly improve the effectiveness, resilience, and safety of water rescue training.

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