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Resting Heart Rate Responses After Three Months of Intensive Exercise

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Abstract

Introduction: Resting heart rate (RHR) is a key indicator of cardiovascular adaptation in athletes, reflecting physiological responses to intensive training. While decreased RHR typically signifies improved cardiovascular efficiency, variability in adaptation based on factors like training duration, intensity, and individual characteristics remains understudied in young athletes. **Objectives:** This study aims to analyze the resting heart rate (RHR) response in young athletes after participating in an intensive 15-week training program. **Method:** The study uses a quasi-experimental design with a pre-test and post-test approach. The sample consists of 15 male and female athletes who are members of the National Sports Design Program (DBON). Physiological variables were measured using digital devices: a heart rate monitor for RHR, a pulse oximeter for oxygen saturation (SpO_2), and a digital scale and height measurer to calculate body mass index (BMI). Measurements were taken before and after the training program. Data were analyzed descriptively (Mean ± SD), and statistical tests were performed using SPSS software. Normality was tested using the Shapiro-Wilk test, and homogeneity of variance was tested using Levene's test. Paired t-tests were used to determine differences between pre- and post-values, while Pearson correlation tests were used to examine relationships between variables, with significance set at $p < 0.05$. **Result:** The results showed no significant changes in RHR, SpO_2, or BMI, and no significant relationship was found between RHR and SpO_2. **Conclusion:** This study recommends long-term physiological monitoring and the use of additional parameters to assess exercise adaptation more comprehensively.

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INTRODUCTION

Changes in resting heart rate in young athletes after intensive training are an essential indicator reflecting the body's physiological adaptation to increased training loads (Morales & Fallon, 2019; Słomko et al., 2018). A decrease in resting heart rate is often identified as an indicator of increased efficiency of cardiovascular capacity, reflecting the body's physiological adaptation to increased intensity of physical activity (Pieles & Stuart, 2020). Research conducted on a group of young athletes aged 13–15 years shows that intensive physical exercise plays a role in stimulating physiological changes, including a decrease in resting heart rate as a manifestation of increasing the heart's efficiency in blood circulation (Shanthi, 2021). This phenomenon generally correlates with left ventricular hypertrophy and increased aerobic capacity, two aspects that contribute significantly to the optimization of performance in adolescent athletes (Bjerring et al., 2021). In addition, these adaptations also influence the physiological response to training loads and speed up the recovery process after intensive training (Gongga & Lee, 2025; Nieto-Jiménez et al., 2020; Zhang, 2022). Therefore, a deep understanding of the dynamics of these physiological changes is essential in designing training programs that are adaptive to the biological development phases of young athletes to support optimal performance in various sporting disciplines.

The phenomenon of changes in resting heart rate in young athletes after intensive training is closely related to the basic principles of physiological adaptation in sports training. Cardiovascular adaptation, which includes increasing the efficiency of cardiac function, is a biological response to exposure to a structured and systematically progressive training load (Govette & Di Salvo, 2022). This decrease in resting heart rate reflects a process known as "athlete's heart," namely morphological adaptations in the form of an increase in left ventricular mass, an increase in systolic volume, and overall cardiovascular system efficiency (Dawkins et al., 2020; Sundin et al., 2020). The theoretical basis of this research refers to the theory of physiological adaptation to intensive exercise, which asserts that the body will develop cardiovascular efficiency mechanisms in the face of consistently increased physical demands. In this case, a decrease in resting heart rate can be used as an indicator of the success of a training program and its effectiveness in improving the performance of young athletes, as well as optimizing the body's recovery after intensive training (Flatt & Esco, 2016; Mathias, 2016; Vacher et al., 2016). Another important variable is the speed of recovery, which shows how the body can return to normal conditions after facing a heavy training load and the relationship between training and changes in the autonomic nervous system that affect the balance between parasympathetic and sympathetic activity.

Although a decrease in resting heart rate has been widely recognized as a positive indicator of physiological adaptation to exercise in young athletes, there remains a void in a deeper understanding of how variables such as gender, type of sport, and initial physical condition influence this response. For example, research by (Zaidah, 2016) demonstrated differences in resting heart rate based on gender and type of exercise but did not specifically investigate the effects of different exercise protocols on these physiological changes. In addition, (Biswas, 2020) found that cricket athletes had lower resting heart rates than other athletes and non-athletes, indicating adaptive variability that is not yet fully understood in the specific context of this type of sport. (Ravé & Fortrat, 2016) suggested that heart rate variability (HRV) in the standing position shows higher sensitivity in identifying adaptive responses to intermittent exercise, as in soccer. However, the generalization of these findings to the youth athlete population and to other sports still does not have a strong basis. Therefore, further research is needed to examine the influence of age, gender, and differences in sports characteristics on the cardiovascular adaptation process due to intensive training to support the design of training programs that are more personalized and based on scientific evidence.

METHOD

This study was conducted using a quasi-experimental design through a one-group pre-test and post-test approach, which aims to evaluate the impact of the training program on changes in resting heart rate (RHR) as an indicator of physiological adaptation of athletes. The research location was in the National Sports Grand Design (DBON) training environment, and activities were carried out over three months, from January to April 2024. The research subjects consisted of 19 young athletes aged 13 to 16 who were members of the DBON coaching program, representing the sports of rock climbing, athletics, archery, and weightlifting. The samples involved in this study consisted of participants who met the inclusion criteria, namely those who were willing to participate fully in the entire training program and research procedures, and who were in good health, thereby enabling them to actively participate throughout the program.

The data collection technique was conducted by measuring RHR using a Pulse Oximeter in two stages: before (pre-test) and after (post-test) the training intervention (Nainggolan, 2017). Measurements were taken under standard conditions, namely when the subject was in an upright sitting position, in a calm state, and after a minimum of five minutes of rest, with three data collection times at each stage, and the lowest consistent result was used as the principal value. The training program provided was a combination of aerobic and resistance training structured around the principles of periodization and progressivity, implemented over 15 weeks with gradually increasing intensity. Training is conducted five times a week, from Monday to Friday. Each training session starts at 3:00 p.m. and typically ends at around 6:45 p.m., except on Fridays, when the session concludes earlier at 5:45 p.m. The total duration of each day's training ranges from 3 to 3.5 hours, depending on the type of exercise and the rest time between sets. All sessions consist of three main components: warm-up, drill technique, and main training, followed by a cool-down. The program includes various types of training, such as core training, upper and lower body strength training, circuit training for endurance, as well as speed, agility, and coordination exercises, providing a comprehensive and structured training load throughout the week.

Data analysis in this study was conducted to answer the main objective, which was to analyze changes in resting heart rate (RHR) as an indicator of physiological adaptation after an intensive training program for 15 weeks, as well as to examine the relationship between RHR and oxygen saturation (SpO_2) and body mass index (BMI) in young athletes. Data were analyzed using SPSS software. Descriptive data for each variable (RHR, SpO_2, and BMI) were presented as mean ± standard deviation (SD) to describe physiological conditions before and after the intervention.

Data normality was tested using the Shapiro-Wilk test, while homogeneity of variance was tested using Levene's test. If the data met the assumptions of normality and homogeneity, a paired t-test was used to determine the significance of changes in pre-test and post-test values for each physiological variable. Furthermore, to analyze the relationship between changes in RHR and SpO_2, as well as BMI, Pearson correlation analysis was employed. The significance level was set at $p < 0.05$. This approach was chosen to suit the research objectives, namely to evaluate not only changes in RHR values directly, but also their patterns of association with other physiological variables as a form of systemic adaptation to long-term exercise load.

RESULT AND DISCUSSION

This study involved 19 participants, 7 male and 12 female. Table 1 presents the characteristics of the participants, including their age, height, weight, and body mass index (BMI).

Table 1. Characteristics of participants

Variable	Group	
	Male (N=7)	Female (N=7)
Age (year)	14.6 ± 0.8	14.3 ± 0.9
Height (cm)	165.1 ± 3.9	161.3 ± 6.1
Weight (kg)	58.2 ± 9.0	55.9 ± 10.1
BMI(Kg/m2)	21.5 ± 4.2	21.4 ± 3.1

Table 2. Physiological Responses of DBON Athletes

Variable	Group			
	Male (N=7)		Female (N=12)	
	Pre	Post	Pre	Post
RHR (beat/minute)	87.6 ± 11.8	98.6 ± 17.8	84.2 ± 13.6	86.3 ± 16.8
SPO_2 (%)	98.1 ± 0.9	97.1 ± 2.0	97.9± 0.5	97.1 ± 2.1
BMI (kg/m^2)	21.5 ± 4.2	21.7 ± 4.1	21.4 ± 3.1	21.5 ± 2.8

The study results on resting heart rate (RHR) showed an increase in both groups. In the male group, RHR increased from 87.6 ± 11.8 to 98.6 ± 17.8 beats per minute, while in the female group, RHR increased from 84.2 ± 13.6 to 86.3 ± 16.8 beats per minute. In addition, there was a slight decrease in SpO_2 values, both in men (from 98.1 ± 0.9% to 97.1 ± 2.0%) and women (from 97.9 ± 0.5% to 97.1 ± 2.1%). Body mass index (BMI) showed stability, with values in men from 21.5 ± 4.2 to 21.7 ± 4.1 kg/m², and in women from 21.4 ± 3.1 to 21.5 ± 2.8 kg/m². This reflects the physiological adaptation that occurs without significant changes in body composition.

Table 3. Correlation between RHR, SPO2 and BMI

Variable		Group		
		BMI (pre)	RHR (pre)	SPO2 (pre)
BMI (pre)	Pearson's r	-		
	p-value	-		
	Lower 95% CI	-		
	Upper 95% CI	-		
RHR (pre)	Pearson's r	-0.176	-	
	p-value	0.472	-	
	Lower 95% CI	-0583	-	
	Upper 95% CI	0.303	-	
SPO2 (pre)	Pearson's r	-0.329	-0.116	-
	p-value	0.169	0.635	-
	Lower 95% CI	-0.681	-0.542	-
	Upper 95% CI	0.147	0.357	-

*p < .05, ** p < .01, *** p < .001

The Pearson correlation analysis showed a very weak and statistically non-significant negative correlation between resting heart rate (RHR) and oxygen saturation (SpO_2) (r = -0.116, p = 0.635), indicating no meaningful association between the two variables in this study.

The findings of this study indicate that there were no statistically significant changes in resting heart rate (RHR), oxygen saturation (SpO_2), or body mass index (BMI) after a 15-week intensive training program involving adolescent athletes. As shown in Table 2, both male and female participants experienced a slight increase in mean RHR post-training. In contrast, SpO_2 levels showed a slight decline, and BMI values remained stable across both groups. From a physiological standpoint, RHR is one of the most frequently used indicators to assess cardiovascular efficiency and overall athletic adaptation to exercise. A lower RHR is typically associated with enhanced stroke volume, improved cardiac output, and increased parasympathetic activity, all of which are hallmarks of a well-trained heart (Plowman & Smith, 2013). This condition, often referred to as "athlete's heart," reflects long-term structural and functional adaptations to endurance training, including left ventricular hypertrophy and improved myocardial efficiency (Sharma et al., 2015).p

However, the absence of a significant decrease in RHR in this study suggests that the physiological load provided during the 15-week training program may not have been sufficient in terms of intensity, volume, or individual specificity to induce measurable cardiovascular adaptation within the observed timeframe. Previous studies have shown that adaptations in RHR may vary widely depending on the sport, training status, and baseline fitness levels of the participants. Furthermore, inconsistencies in training adherence, inter-individual differences in response to exercise stimuli, and the varying maturational stages among adolescent participants may have also contributed to the non-significant findings.

Although the 15-week intensive exercise program did not result in significant changes in resting heart rate (RHR), oxygen saturation (SpO_2), or body mass index (BMI), the correlation analysis between RHR and SpO_2 showed a very weak and insignificant negative relationship ($r = -0.116$; $p = 0.635$). These results indicate that there is no statistically significant association between the cardiovascular and respiratory systems based on the parameters observed in this study. These findings differ from previous studies that have shown correlations between physiological parameters as part of the adaptive mechanism to exercise. This may be due to individual variability, adherence to exercise intensity, or the varying age ranges and sports disciplines among the study subjects.

From a performance perspective, resting heart rate is not only an indicator of cardiovascular efficiency but also a sensitive marker of training load, overtraining, and recovery status (Buchheit, 2014; Plews et al., 2013). Elevated RHR over time may indicate insufficient recovery or excessive fatigue, which can impair athletic performance (Stanley et al., 2013). Therefore, monitoring RHR trends longitudinally, rather than focusing solely on pre-post comparisons, may provide more informative insights into training effectiveness.

The limitations of this study should be acknowledged. The relatively small sample size, gender imbalance, and inclusion of athletes from multiple sports disciplines without subgroup analysis may limit the generalizability of the results. Moreover, the absence of a control group restricts tpusphe ability to attribute observed physiological changes solely to the training intervention. Future research should consider larger samples, sport-specific analyses, and include additional markers of autonomic regulation such as heart rate variability (HRV) to more comprehensively evaluate the adaptations of youth athletes to structured training.

CONCLUSION

This study demonstrates that a 15-week intensive training program did not yield significant changes in resting heart rate (RHR), oxygen saturation (SpO_2), or body mass index (BMI) in young athletes. Additionally, no significant relationship was found between RHR and SpO_2, indicating that physiological adaptation responses to exercise are complex and may vary among individuals. For future research, it is recommended to involve a larger sample size, conduct longitudinal physiological monitoring, and utilize additional parameters, such as heart rate variability (HRV), to obtain a more comprehensive understanding of cardiovascular and respiratory adaptation to long-term training programs.

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