

Is there a correlation between age and heart rate recovery in amateur runners after the Cooper test?

Existe correlação entre idade e recuperação da frequência cardíaca em corredores amadores após Teste de Cooper?

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ABSTRACT

Introduction: Heart rate (HR) recovery after exercise is widely used as an indicator of autonomic modulation and aerobic fitness. However, the influence of age on this process remains unclear in amateur runners. **Objective:** This study aimed to analyze the correlation between age and HR during recovery at different moments after the Cooper Test. Twenty-two male amateur runners, aged 20 to 39 years, were evaluated. **Methods:** HR was measured at rest (F0), immediately post-test (F1), and five minutes post-exercise (F2). Data normality was verified using the Shapiro-Wilk test, and Spearman's correlation coefficient was applied to assess the relationship between age and HR. **Results:** A strong and statistically significant negative correlation was found between age and HR at F1 ($r = -0.997$; $p < 0.001$) and F2 ($r = -0.991$; $p < 0.001$), indicating that older individuals exhibited lower HR values post-exercise. **Conclusion:** These findings suggest that age influences the chronotropic response to exercise, with older individuals reaching lower peak HR values and subsequently presenting lower HR values during early recovery. This pattern does not necessarily reflect faster recovery but may be associated with reduced sympathetic activation during exertion. Future studies should incorporate direct measurements of autonomic modulation and aerobic fitness to provide a deeper understanding of this relationship.

Keywords: heart rate; autonomic nervous system; age

RESUMO

Introdução: A recuperação da frequência cardíaca (FC) após o exercício é amplamente utilizada como indicador da modulação autonômica e da aptidão aeróbia. No entanto, a influência da idade nesse processo em corredores amadores ainda não está totalmente esclarecida. **Objetivo:** Analisar a correlação entre idade e FC durante a recuperação em diferentes momentos após o Teste de Cooper. Participaram 22 corredores amadores do sexo masculino, com idades entre 20 e 39 anos. **Método:** A FC foi registrada em repouso (F0), imediatamente após o teste (F1) e cinco minutos após o esforço (F2). A normalidade dos dados foi verificada pelo teste de Shapiro-Wilk, e a correlação entre idade e FC foi avaliada pelo coeficiente de Spearman. **Resultados:** Observou-se correlação negativa forte e significativa entre idade e FC em F1 ($r = -0,997$; $p < 0,001$) e F2 ($r = -0,991$; $p < 0,001$), indicando que indivíduos mais velhos apresentaram valores menores de FC pós-esforço. **Conclusão:** Esses achados sugerem que a idade influencia a resposta cronotrópica ao esforço, com indivíduos mais velhos atingindo menores picos de FC e, conseqüentemente, exibindo valores mais baixos durante a recuperação inicial. Isso não implica necessariamente em recuperação mais rápida, mas pode refletir menor ativação simpática durante o exercício. Estudos futuros devem incorporar medidas diretas da modulação autonômica e da aptidão aeróbia para aprofundar a compreensão dessa relação.

Palavras-chave: frequência cardíaca; sistema nervoso autônomo; idade

Introduction

Heart rate recovery after intense exercise has been widely used as an indicator of cardiac autonomic modulation and aerobic fitness. Heart rate is a fundamental physiological variable for training prescription and for monitoring exercise load in both amateur and professional athletes [1]. The ability of heart rate to recover reflects the efficiency of sympathetic withdrawal and parasympathetic reactivation at the end of exercise, and it may be associated with lower cardiovascular risk and improved athletic performance [2]. However, the influence of age on this process is not yet fully understood, particularly among amateur road runners.

Studies suggest that the heart rate response to exercise and its recovery are modulated by autonomic adjustments, in which the withdrawal of sympathetic activation and the restoration of parasympathetic tone occur at different stages of recovery [3]. Nevertheless, this relationship may vary according to age. Some studies indicate that younger individuals tend to reach higher heart rate values during maximal exertion and exhibit a more pronounced deceleration during the early phase of recovery, whereas older individuals may show smaller initial changes in HR during this period [4]. However, the mechanisms underlying these differences remain under debate and may involve factors such as aerobic fitness, training load, and individual characteristics of the autonomic nervous system.

Therefore, the present study aimed to analyze the correlation between age and heart rate recovery after the Cooper Test in amateur runners. The central hypothesis was that there is a negative relationship between age and HR immediately after the test, suggesting that older individuals tend to have lower absolute post-exercise HR values. However, this relationship does not necessarily imply faster recovery, as it may be associated with factors such as lower sympathetic activation during exercise and lower peak HR achieved. The findings of this study may contribute to improving individualized training prescription strategies, assisting in intensity control and optimizing post-exercise recovery across different age groups.

Methods

This is a cross-sectional study conducted and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines. The study was approved by the Ethics Committee of the State University of Goiás (Resolution 466/12). All volunteers were informed about the procedures to which they would be subjected and signed an informed consent form.

Participants

Male amateur runners aged between 20 and 45 years who had been regularly practicing road running for at least six months were included in the study. Participants were recruited voluntarily through convenience sampling and were informed

about the study procedures prior to signing the informed consent form. To ensure sample homogeneity, specific inclusion criteria were established. Only individuals affiliated with a private higher education institution in the city of Anápolis, Goiás, Brazil, and duly registered with the Brazilian Athletics Confederation (CBAt), were eligible to participate. In addition, only healthy athletes with no history of cardiovascular, metabolic, or neuromuscular diseases that could compromise the physiological response to the test were included. Individuals with recent musculoskeletal injuries, using medications known to affect the autonomic modulation of heart rate, or who did not complete all stages of the evaluation protocol, were excluded.

Variables

Physiological and anthropometric variables were analyzed to investigate the correlation between age and heart rate behavior at different post-exercise time points. The primary variable was heart rate, measured at three distinct time points: at rest (F0), immediately after the Cooper Test (F1), and five minutes after exertion (F2). In addition, sociodemographic and anthropometric variables were collected, including age, body weight (in kilograms), height (in meters), and body mass index (BMI), calculated using the equation $\text{weight}/\text{height}^2$. The cardiovascular response during the test was monitored using a digital heart rate monitor, ensuring continuous and accurate recording of heart rate variations.

Procedures

The evaluation procedures were conducted in a controlled environment to ensure standardized conditions for data collection. Participants were instructed to refrain from consuming alcoholic beverages, caffeine, and/or other stimulating substances, as well as to avoid strenuous exercise during the 24 hours before the test. They were also advised to consume a light meal at least two hours prior to the assessment. On the testing days, participants were required to wear comfortable clothing and suitable running shoes. Before data collection, they were asked about their general health status and sleep quality on the previous night to ensure that they were fit to participate in the procedures.

Test protocols

Aerobic exercise test

Participants underwent the Cooper Test, a protocol widely used to assess aerobic capacity, consisting of a continuous maximal-intensity run for 12 minutes on an official athletics track [5]. The purpose of the test was to evaluate the heart rate response to exercise and cardiovascular recovery at different post-exercise time points. During the test, heart rate was continuously monitored using a Garmin Forerunner 920XT digital heart rate monitor, ensuring accurate recordings of heart rate variation throughout the test. Blood pressure was measured before and after the test using a digital sphygmomanometer (Omron HEM-7130), and peripheral oxygen

saturation (SpO_2) was assessed using a portable pulse oximeter (Yonker YK-81A) to monitor blood oxygenation during recovery.

Maximum heart rate was estimated using the equation $\text{HR}_{\text{max}} = 208 - (0.7 \times \text{age})$ [6], which was used as a reference to analyze the level of exertion reached by the participants. Heart rate data were collected at three distinct time points: at rest (F_0), prior to the beginning of the test, with participants seated for at least five minutes; post-test (F_1), immediately after the completion of the run, recording the maximum heart rate achieved; and five minutes after exertion (F_2), assessing the initial phase of heart rate recovery.

All tests were conducted at the same time of day to minimize the effects of circadian variations. A rigorous standardization protocol was followed to ensure data reliability. Criteria for test interruption included signs of physical exhaustion, complaints of dizziness, discomfort, or any physiological alteration that could compromise participant safety.

Statistical analysis

Statistical analysis was performed using Jamovi® software, version 0.7.2.6. Initially, descriptive statistics were conducted, including the calculation of mean, standard deviation, minimum and maximum values for the variables age, body mass, height, body mass index (BMI), and heart rate (HR) at the different time points evaluated. Additionally, the variation (Δ) between resting HR (F_0) and post-test HR (F_1), as well as the variation (Δ) between F_1 and five minutes after exertion (F_2), were quantified (final HR – initial HR). Percentage differences were also calculated between F_0 and F_1 and between F_1 and F_2 . Data normality was assessed using the Shapiro–Wilk test. The results indicated that resting HR (F_0) followed a normal distribution ($p \geq 0.05$), whereas post-test HR (F_1) and HR five minutes after exertion (F_2) did not follow a normal distribution ($p < 0.05$), justifying the selection of appropriate statistical tests for each analysis.

To evaluate the relationship between age and heart rate recovery at the different time points following the Cooper Test, Spearman's correlation coefficients were calculated. This test allowed determination of the strength and direction of the correlation between age and HR during phases F_1 and F_2 . The interpretation followed the criteria proposed by Dancey and Reidy [7], in which values close to ± 1 indicate a strong correlation, values between ± 0.30 and ± 0.70 indicate a moderate correlation, and values below ± 0.30 indicate a weak correlation.

Results

Anthropometric characteristics

A total of 22 male amateur runners were evaluated. The mean age of the participants was 26.3 ± 5.3 years, ranging from 20 to 39 years. The mean body mass was 73.3 ± 8.6 kg, with values ranging from 60 to 89 kg. The mean height recorded was 172 ± 6.0

cm, ranging from 158 to 183 cm. The mean body mass index (BMI) was 24.9 ± 2.5 kg/m², with a minimum of 20.0 kg/m² and a maximum of 26.5 kg/m². Table I presents the characteristics of the sample, including measures of central tendency and dispersion (n = 22).

Table I - Characterization of the participants (n = 22)

Variables	Mean	Minimum value	Maximum value
Age (years)	26.3 ± 5.3	20	39
Body mass (kg)	73.3 ± 8.6	60	89
Height (m)	1.72 ± 6.0	158	183
BMI (kg/m ²)	24.9 ± 2.5	20.0	26.5

BMI = Body Mass Index. Continuous variables are expressed as mean and standard deviation (SD)

The results obtained from the analysis of heart rate at different moments of the Cooper Test revealed variations between the resting and recovery phases. The resting heart rate (F0) had a mean value of 70.3 ± 10.2 bpm, which reflects the participants' baseline state before the test. After the Cooper Test, a marked increase in heart rate was observed immediately post-exercise (F1), reaching a mean of 181.0 ± 3.5 bpm, a value close to the estimated maximum heart rate for the sample (≈ 190 bpm), calculated based on the equation proposed by Tanaka et al. [6]. The variation (Δ) between the means was 110.7 bpm, representing an average increase of 147.46%. This increase was expected, as it reflects the cardiovascular response to high-intensity exercise. However, after five minutes of recovery (F2), heart rate showed a significant mean reduction to 150.0 ± 3.0 bpm (a variation of 31 bpm or 17.12%), indicating the onset of parasympathetic reactivation and the progressive autonomic recovery following exertion. Table II presents the central and dispersion values of heart rate at the different time points of the test, including minimum and maximum values and the variations between the different phases of the protocol.

Table II - Mean (SD) heart rate and variations (Δ) at different time points after the Cooper Test (n = 22)

Variables	Mean (bpm)	Minimum value (bpm)	Maximum value (bpm)	Variation (Δ) between F0 and F1 (bpm)	Variation between F1 and F2 (bpm)
Resting heart rate (F0)	70.3 $\pm$ 10.2	54	88	110.7	-
Post-test heart rate (F1)	181 $\pm$ 3.5	173	185		31
Heart rate 5 minutes after (F2)	150 $\pm$ 3.0	143	154	-	

HR = Heart rate. Continuous variables are expressed as mean and standard deviation (SD)

The analysis of the correlation between age and heart rate at different time points of the Cooper Test revealed a significant relationship between these variables. Table III presents the Spearman correlation coefficients (r) and the corresponding statistical significance values (p) for the analyzed moments: resting (F0), immediately after the test (F1), and five minutes after exertion (F2). A strong and statistically significant negative correlation was observed between age and heart rate immediately after the test (F1, $r = -0.997$; $p < 0.001$) and between age and heart rate five minutes after exertion (F2, $r = -0.991$; $p < 0.001$). These findings indicate that as age increases, heart rate values at the post-test moments tend to be lower, suggesting an inverse relationship between age and heart rate during the initial recovery phase. In addition, a weak negative correlation was observed between age and resting heart rate, without statistical significance (F0, $r = -0.026$; $p = 0.910$), indicating that age did not exert a relevant influence on the participants' baseline heart rate.

Table III - Correlation between age and heart rate at different time points after the Cooper Test (n = 22)

Time point	Correlation coefficient (r)	p-value
Resting heart rate (F0)	-0.026	0.910
Post-test heart rate (F1)	-0.997	<0.001*
Heart rate 5 minutes after (F2)	-0.991	<0.001*

*Statistically significant. HR = Heart rate

Discussion

The present study aimed to analyze the correlation between age and heart rate recovery at different time points following the Cooper Test in amateur runners. Our initial hypothesis suggested that age would significantly influence the heart rate response after exertion, with younger athletes showing a greater initial variation in heart rate and older athletes demonstrating an apparently faster recovery, possibly due to lower peak heart rate values during maximal effort. The findings of the study indicated that there is a negative correlation between age and heart rate

immediately after the test (F1). This suggests that, as age increases, post-exercise heart rate tends to be lower.

This result may be related to individual differences in the cardiovascular response to exercise; however, it does not allow us to conclude that age alone is responsible for this variation, since factors such as physical fitness and individual physiological characteristics may also influence this relationship. In this context, the high correlation coefficients may suggest a structural dependency between age and HR, possibly amplified by the physiological decline in maximal heart rate with aging, rather than necessarily reflecting a genuine physiological relationship with autonomic recovery.

Previous studies have shown that heart rate recovery is modulated by the autonomic balance between the sympathetic and parasympathetic systems. This process is more efficient in individuals with higher aerobic fitness and lower residual sympathetic activation after exercise [8]. However, while the literature often suggests that younger individuals tend to recover heart rate more rapidly due to greater heart rate variability and more efficient vagal reactivation [9], our findings show that older runners had lower heart rate values immediately after the test. This relationship does not allow us to conclude directly that older individuals exhibit faster heart rate recovery, but it does suggest that the chronotropic response to exercise may be lower with increasing age, which could influence the perception of immediate recovery [10].

A possible explanation for this phenomenon is that the chronotropic response to exercise decreases with age, leading to a reduction in the maximum heart rate achieved during exertion [10]. This factor may create the false impression that older individuals recover heart rate more quickly, when in fact the lower magnitude of the initial sympathetic response makes heart rate deceleration appear more efficient [11]. However, this hypothesis would require further investigation using direct measurements of autonomic activity, such as heart rate variability (HRV), in order to confirm whether differences exist in sympathetic and parasympathetic activation across different age groups.

Among the limitations of this study, the small sample size and the lack of control for factors such as participants' level of aerobic fitness should be highlighted, which may overestimate the observed associations and reduce external reliability. Although all participants were amateur runners officially registered with the athletics federation, differences in training volume and intensity may influence heart rate recovery, since individuals with higher aerobic fitness tend to exhibit more efficient recovery [11]. In addition, because the study relied solely on correlation analysis, it was not possible to evaluate the influence of other potentially relevant variables, such as training load and years of sports practice, which could independently affect heart rate recovery regardless of age. Furthermore, the analysis of heart rate recovery was based on absolute HR values and their absolute and percentage variations at different time points of the Cooper Test, rather than using metrics such as Heart Rate

Recovery (HRR), defined as the decrease in HR during the first minute after exercise, which should exceed 12 bpm.

Based on these results, future studies should further investigate the interaction between age, aerobic fitness, and autonomic activation during exercise and recovery. Understanding these relationships may contribute to the development of more effective training prescription strategies, assisting in the control of exercise intensity and in optimizing post-exercise recovery for different athlete profiles [12]. In addition, future research may consider including direct measurements of autonomic activation (e.g., heart rate variability) and aerobic fitness (e.g., $\text{VO}_{2\text{max}}$) in order to more accurately differentiate the effects of age and fitness level on heart rate recovery.

Conclusion

The findings of this study indicated a negative correlation between age and heart rate immediately after the Cooper Test, suggesting that older individuals tend to have lower post-exercise HR values. However, this relationship does not necessarily imply faster HR recovery, as the lower post-test HR may be associated with reduced sympathetic activation and a lower maximal heart rate achieved during exertion.

Conflict of Interest

The authors declare that there are no financial, commercial, personal, or political conflicts of interest related to the subject and development of this article.

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Author contributions

Study conception and design: Soares WI, Santana F; Data collection: Soares WI; Data analysis and interpretation: Soares WI, Marques VA, Silva NP, Oliveira FB; Statistical analysis: Soares WI, Santana F; Funding acquisition: not applicable; Manuscript writing: Santana F, Marques VA, Silva NP, Oliveira FB; Critical revision of the manuscript for important intellectual content: Santana F, Marques VA, Silva NP, Oliveira FB.

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