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Original Article

Age influence on the magnitude of heart rate recovery in trained athletes

A influência da idade sobre a magnitude de recuperação da frequência cardíaca em indivíduos treinados

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ABSTRACT

Introduction: Heart rate recovery (HRR), defined as a decline in heart rate (HR) after exercise, is controlled by neurohumoral factors. There are two observed phases of HRR, the fast (vagal reactivation), which comprises the initial period between 60 and 120 seconds and the slow (sympathetic withdrawal), which goes until the return to rest values. Several factors may influence HRR, such as fitness level, gender, age and others. **Objective:** To test the hypothesis that there is a difference in the decline in HRR between trained adults and teenagers. **Methods:** 58 male soccer players were evaluated, divided into two groups: Teenagers (TG) and Adults (AG) aged 16.4 ± 0.5 and 27.9 ± 0.9 years, respectively. Anthropometric, HR and blood pressure analyzes were performed. **Results:** Both groups reached and exceeded the maximum heart rate (HRmax) predicted by age. The observed values were similar at the end of the HRR fast phase, while at the end of the slow phase the TG group obtained significantly higher values. Values of $P<0.05$ were considered significant. **Conclusion:** The results of the fast phase show that high levels of physical conditioning seem to attenuate the deleterious effect of age on vagal reactivation. The same effect was not observed on the sympathetic withdrawal during the slow phase; therefore, the TG group obtained higher HRR values during this period.

Key-words: Autonomic nervous system, Stress test, Heart rate, Adult, Teenagers.

RESUMO

Introdução: A recuperação da frequência cardíaca (RecFC), definida como declínio da frequência cardíaca (FC) após o exercício, é controlada por fatores neuro-humorais. Há duas fases observadas da RecFC, a rápida (reativação vagal), que compreende o período inicial entre 60 e 120 segundos e a lenta (retirada simpática), que vai até o retorno aos valores de repouso. Diversos fatores podem influenciar a RecFC, como o nível de condicionamento físico, o gênero, a idade e outros. **Objetivo:** Testar a hipótese de que existe diferença no declínio da RecFC entre adultos e adolescentes treinados. **Métodos:** Foram avaliados 58 jogadores de futebol, sexo masculino, divididos em dois grupos: Adolescentes (GJ) e Adultos (GA), com idade de 16,4 ± 0,5 e 27,9 ± 0,9 anos, respectivamente. Análises antropométricas, de FC e pressão arterial foram realizadas. **Resultados:** Ambos os grupos atingiram e ultrapassaram a frequência cardíaca máxima (FCmax) prevista pela idade. Os valores observados foram similares ao final da fase rápida da RecFC, enquanto ao final da fase lenta o grupo GJ obteve valores significativamente maiores. Valores de $P< 0,05$ foram considerados significantes. **Conclusão:** Os resultados da fase rápida apontam que altos níveis de condicionamento físico parecem atenuar o efeito deletério da idade sobre a reativação vagal. O mesmo efeito não foi observado sobre a retirada simpática durante a fase lenta, sendo assim, o grupo GJ obteve maiores valores de RecFC durante este período.

Palavras-chave: Sistema nervoso autônomo, Teste de esforço, Frequência cardíaca, Adulto, Adolescente.

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Introduction

Physical exercise is a stimulus that causes important adjustments in the functioning of the cardiovascular system and its modulation by the autonomic nervous system [1]. When starting physical activity, one of the earliest effects on the cardiovascular system is the increase in heart rate (HR). This increase is due to changes in the balance of the sympathetic and parasympathetic components that control the cardiovascular system, acting with the release of neurotransmitters that may increase or decrease the heart rate. The initial increase in HR occurs due to the decrease in the vagal component, followed by a progressive intensification of the activity of the sympathetic component, proportional to the intensity of the exercise [2-5]. At the end of physical activity, cardiac autonomic function gradually returns to resting conditions and HR reduces [6].

Heart rate recovery (HRR) may be defined as the decline in HR after stopping exercise. Its behavior has been investigated by several research groups and may be divided into two phases: fast and slow. The rapid phase comprises the initial period of HRR, lasting between 60 and 120 seconds, with an abrupt decrease in HR, largely determined by vagal reactivation. The slow phase comprises the entire period after the fast phase until the return of HR to its resting values, caused by the sympathetic withdrawal and a progressive increase in vagal activity [6,7].

In a cohort study conducted by Cole *et al*. [8] with 2428 patients followed for six years, it was observed that a value equal to or less than 12 beats per minute of HRR in the first minute after physical effort was considered abnormal and strongly predictive of mortality, with a relative risk 4 times higher for individuals who had abnormal HRR values (≤12 beats per minute) when compared to the group with normal values.

The relationship between good physical fitness and improved HRR in different populations is already well established. Physical training promotes changes in the neural components that act on the heart, which influences the acceleration of HRR after exercise [9-11]. Another relevant factor is that changes in acute training loads may promote changes in this measure [12]. Thus, HRR may be used as an important tool for training prescription and monitoring [13-15].

Although important, the level of training is not the only determinant of HRR. Factors such as age, gender and race may potentially interfere in both the fast and the slow phase of HRR [6,16]. The effect of age was demonstrated by Buchheit *et al*. [17], who obtained a faster HRR in the group of children; no differences were observed between the groups of teenagers and adults. Buchheit *et al*. [18] observed a difference between the HRR of teenager soccer athletes in the sub-15 category and in the sub-17 category, with a better index for younger individuals.

The scientific literature on differences in HRR in athletes of different ages is still scarce, so the objective of the study was to test the hypothesis that there is a difference in the decline in HRR between trained adults and teenagers.

Methods

Research sample

The sample of this study was composed of 58 well-trained male soccer athletes, without pre-existing diseases. The individuals were divided into two groups: teenagers (TG), with 30 individuals and age of 16.4 ± 0.5 years and adults (AG), with 28 individuals and age of 27.9 ± 0.9 years. The study included individuals who practice soccer at least 6 times a week for at least 3 years. The athletes could not present injuries at the time of the evaluations. Participants were assessed at two different times. All assessments took place at the Laboratory for Integrative Analysis of Physical Exercise at Leforte Hospital.

All participants gave their consent to participate in the study by signing the Terms of Free and Informed Consent (ICF), under 18 years old, the ICF was signed by the parents. The procedures used respect the international human experimentation standards of resolution 466/12 [19]. The ethics committee of Santa Cecília University approved the study (opinion number: 2,916,298 and CAAE: 90992618.6.0000.5513).

Anthropometric assessments

Participants were assessed at two different times. All assessments took place at the Laboratory for Integrative Analysis of Physical Exercise at Leforte Hospital. Weight measurements were made on both days, using a digital scale (Filizola®), with a maximum capacity of 150 kg with graduations of 100 g; height in stadiometer, graduated in centimeters. The body mass index was calculated using weight and height data.

Ergometric test

The athletes underwent an incremental ergometric test, performed on a treadmill (Centurion, model 200, Micromed, Brazil), speed from 0 to 24 km/h, elevation from 0 to 26% and weight capacity of 200 kg. The same ramp protocol was used for all study participants, calculating speed and inclination based on the age of the athletes. The protocol called Soccer 1 is adopted and recommended for soccer players and consists of an increase in speed every minute and a fixed inclination of 1%.

The examination room is large enough to accommodate the necessary equipment. The temperature of the room varied between 20°C and 24°C and relative humidity between 60 and 70% to allow an adequate exchange of heat with the medium. A cardiologist performed the evaluation.

The athletes were encouraged to perform the test until the maximum fatigue supported, trying to reach the HRmax estimated by the age, when the athletes could no longer support the effort and the test was interrupted; and the recovery period began, lasting five minutes at rest while standing on the treadmill. At the end of the protocol, we evaluated the total test time performed by the athletes, not counting the five minutes of recovery. The test was considered maximum when individuals reached the HRmax predicted by age (220 – age) and maximum voluntary fatigue. Both criteria should be met.

Measurement of blood pressure and heart rate

The analyzes of systolic blood pressure (SBP) and diastolic blood pressure (DBP) were performed using an arm sphygmomanometer and stethoscope auscultation with individuals standing on the treadmill during rest, every three minutes of test execution and after its completion, during minutes one, two, four and six of recovery. HR was analyzed through an electrocardiogram with the recording of the 12 standard leads (ErgoPC Elite 13) with an individual at rest, standing upright on the treadmill, every minute during test execution and during recovery, in minutes one, two, three, four and five. HRR was calculated as the difference between the HRmax achieved during the test and the HR recorded after 60 (ΔHRR 1), 120 (ΔHRR 2), 180 (ΔHRR 3), 240 (ΔHRR 4) and 300 (ΔHRR 5) seconds, representing the decline in HR during that time interval. During the active recovery period, the subjects walked on the treadmill with a standardized load of 4.0 km/h during the first and second minutes and 3.0 km/h in the third and fourth, the last minute of recovery was performed while standing on the mat, all minutes of recovery were performed without inclination.

Statistical analysis

The data for the present study were presented as mean ± and standard deviation. Statistical tests were performed using the Statistica software (v10.0 StalSoft, Inc., USA). The variables analyzed in this study were subjected to the Shapiro-Wilk test to assess the normality of data distribution, resulting in normal distribution. Anthropometric characteristics data were subjected to statistical analysis Student's t test for non-repeated measurements. To compare the HRR indexes, ANOVA 2-way analysis of variance was used for non-repeated measures in TG and AG. When necessary, the Newman-Keuls test was used as a post-hoc test. For all tests, the level of significance adopted was 5%.

Results

The physiological and hemodynamic variables recorded at rest, before the test is performed, are in Table I. The data were expressed as means and standard deviations. The average age of the groups was 16.4 ± 0.3 years for TG and 27.9 ± 0.2 years for AG and was the only one to present a significant difference between the variables in this table ($p<0.05$).

Table I - Characterization of participants.

	Teenagers (TG) n = 30	Adults (GA) n = 28
Age (years)	16 ± 0.5	28 ± 0.9*
Height (cm)	170 ± 5.6	178 ± 6.3
Body weight (kg)	69 ± 2.3	70 ± 2.5
BMI	24 ± 0.8	22 ± 0.7
Resting SBP (mmHg)	120 ± 4.0	120 ± 4.0
Resting DBP (mmHg)	80 ± 2.6	80 ± 2.9

Data expressed as mean ± and standard deviation; *$p<0.05$; BMI = body mass index; SBP = systolic blood pressure; DBP = diastolic blood pressure.

The data obtained during and after the exercise stress test are in Table II. After the test was interrupted, it was observed that the rapid phase of HRR (1st and 2nd minutes after the test ceased) showed a similar behavior between the two groups. During the slow phase, the HRR presented higher values for the TG group in minutes three, four and five, showing a significant difference between the two groups evaluated ($p<0.05$).

Table II - Heart rate behavior.

	Adolescentes (GJ) n = 30	Adultos (GA) n = 28
Rest		
HR (bpm)	68 ± 2.7	69 ± 2.3
Peak effort		
HRmax (bpm)	205 ± 6.9	194 ± 6.5*
Recovery		
ΔHRR 1 (bpm)	43 ± 6.0	42 ± 1.0
ΔHRR 2 (bpm)	70 ± 5.2	74 ± 4.0
ΔHRR 3 (bpm)	92 ± 5.0	86 ± 3.5*
ΔHRR 4 (bpm)	110 ± 4.0	101 ± 3.3*
ΔHRR 5 (bpm)	123 ± 4.5	106 ± 3.0*

Data expressed as mean ± standard deviation; *$p<0.05$; HR = heart rate; HRmax = maximum heart rate; ΔHRR = HR decline in the time interval between HRmax and the analyzed minute.

Discussion

The present study verified the possible relationship between HRR behavior in groups of adult and teenager athletes. Our results did not show differences in the decline in HR in the first minutes (fast phase) after a maximum effort test with active recovery, when compared to their teenager peers. During the slow phase, the decline in HR was significantly greater in the group of teenagers and exceeded the group of adults in absolute values, a behavior that remained until the last minute analyzed.

The adaptations in cardiac autonomic function resulting from good training levels are known, and are mainly due to the increase in the sympathovagal balance and, consequently, lower HRR values after exercise. This training effect is observed in different populations, both in the elderly after eight weeks of aerobic training [10] and in adults with a higher level of aerobic fitness, there is an increase in autonomic control of post-exercise heart rate, demonstrated by a decrease in HRR, which reflects the preservation of the speed of vagal reentry [20]. Corroborating the importance of physical exercise as an activity that seems to postpone the deleterious effect of age on HRR, a study conducted with trained and untrained subjects of similar ages shows, after maximum effort test, higher HRR values in the group that practices physical exercise [21].

Having the knowledge that high levels of conditioning lead to better HRR rates, several studies were conducted with athletes of different ages and sports, observing the values for this index of measurement of autonomic function [9,17,18,22-24].

Although there is a considerable amount of data with athletes, few sought to observe differences between athletes of the same sport and different ages. An elegant study was conducted comparing the HRR between young and adult athletes after a maximum ramp test. Lazic *et al.* [25] observed better rates of HRR during the first minute in adults, when compared to their teenager peers; however, in the third minute the teenagers already had a significantly higher HRR. These data show some similarities with the findings of our study, mainly with the inversion of HRR values from the third minute, when teenagers seem to have an advantage in relation to their adult peers.

Most of the energy provided during a soccer game is provided by aerobic metabolism, but the result is often decided in anaerobic sprints; therefore, football may be considered an intermittent modality, where both physical capacities are important and must be improved [26].

The importance of aerobic fitness has already been demonstrated in adult individuals for better HRR values [20]. Boullosa *et al.* [27] evaluated the autonomic cardiac adaptations in soccer players after an eight-week training period and found better values for heart rate variability (HRV) and HRR measures, concluding that a pre-season of training has a positive influence on both indexes.

Studies differ in relation to the exercise and recovery protocol used, which may directly influence HR behavior during and after exercise. Maeder *et al.* [28] showed a difference in the first minute of HRR during two different exercise protocols, in healthy subjects and with heart failure. The type of recovery also appears to be a determining variable, since Barak *et al.* [29] found that different recovery protocols influenced the first minute of HRR, both in athletes and non-athletes.

The effects of physical exercise on several control indexes of autonomic functions are widely demonstrated [30-32]. However, as we have shown, these effects also occur in HRR [9,10,20-22,25]. It is worth mentioning that the drop in HRR is a potent prognostic factor that predicts mortality from cardiovascular diseases, even in asymptomatic individuals [33].

Based on data from the current literature, we believe that our findings have great relevance for a better understanding of autonomic responses in athletes of different ages. Our hypothesis is that the training preserves parasympathetic autonomic function, so that in the fast phase, both groups (TG and AG) have similar HRR values. During the slow phase, largely determined by the reactivation of the sympathetic component, the training did not seem to have enough effect for the groups to continue with close values, so, from the third minute onwards, the TG group had a higher HRR.

The present study has limitations, since some measures that may influence the autonomic response after physical exercise, such as maximum oxygen consumption and metabolic thresholds for determining the aerobic fitness of the groups, as well as the time of practice of the evaluated athletes, were not stratified. Future studies are necessary with the evaluation of the mentioned indexes and explaining what are the possible reasons for the effects of physical exercise to act preserving the vagal reentry.

Conclusion

Based on the results, we conclude that high levels of physical training, observed in athletes, act preserving parasympathetic autonomic control after physical effort, attenuating the effects of age in the studied population, which was demonstrated by similar values in the rapid phase of HRR. From this moment on, that is, in the slow phase, the effect of exercise acting on the sympathetic withdrawal was not observed; therefore, it is expected that young athletes recover faster than their adult peers do in this period.

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Academic link
This article represents a scientific initiation by Victor Tavares de Santana, supervised by Professor Doctor Alexandre Galvão da Silva and Professor Doctor Débora Dias Ferraretto Moura Rocco.

Potential conflict of interest
No conflicts of interest have been reported for this article.

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Contribuição dos autores
Conception and design of the research: Santana VT, Rocco DDFM, Silva AG**. Data collection:** Aguillar IN, Santana VT, Rocco DDFM, Silva AG, Rached H. **Analysis and interpretation of data:** Santana VT, Rocco DDFM, Silva AG. **Statistical analysis:** Silva AG. **Obtaining financing:** not applicable. **Writing of the manuscript:** Santana VT, Rocco DDFM, Silva AG**. Critical review of the manuscript for important intellectual content:** Gardenghi G.

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