AGE INFLUENCE ON THE HEART RATE BEHAVIOR ON THE REST-EXERCISE TRANSITION: AN ANALYSIS BY DELTAS AND LINEAR REGRESSION

ABSTRACT

Background: Changes in heart rate during rest-exercise transition can be characterized by the application of mathematical calculations, such as deltas 0-10 and 0-30 seconds to infer on the parasympathetic nervous system and linear regression and delta applied to data range from 60 to 240 seconds to infer on the sympathetic nervous system. The objective of this study was to test the hypothesis that young and middle-aged subjects have different heart rate responses in exercise of moderate and intense intensity, with different mathematical calculations. Methods: Seven middle-aged men and ten young men apparently healthy were subject to constant load tests (intense and moderate) in cycle ergometer. The heart rate data were submitted to analysis of deltas (0-10, 0-30 and 60-240 seconds) and simple linear regression (60-240 seconds). The parameters obtained from simple linear regression analysis were: intercept and slope angle. We used the Shapiro-Wilk test to check the distribution of data and the “t” test for unpaired comparisons between groups. The level of statistical significance was 5%. Results: The value of the intercept and delta 0-10 seconds was lower in middle age in two loads tested and the inclination angle was lower in moderate exercise in middle age. Conclusion: The young subjects present greater magnitude of vagal withdrawal in the initial stage of the HR response during constant load exercise and higher speed of adjustment of sympathetic response in moderate exercise.

Keywords: Aging, Methods, Heart Rate

INTRODUCTION

During the transition between rest and dynamics physical exercise alterations of the cardiac rhythm besides of other physiological adjustments take place in an attempt to meet the energetic demand imposed by the active musculature. Some of these alterations may be observed through the application of mathematical adjustments which characterize for example the heart rate behavior (HR) in this transition.

In low-intensity exercise, the initial increase of HR, observed in the first 30s, may be associated to the inhibition of parasympathetic modulation over the sinusal nodule, in order to rapidly increase the peripheral blood flow as well as supply the energetic demand imposed by the muscle tissues involved in the task performance. After about 30s, decrease in HR derived from the parasympathetic reactivation on the sinusal node secondary to the increase in venous return and consequent increase of ejection volume, detected by the arterial and/or carotid baroreceptors can be observed. After this period, with exercise continuity, the HR increases again when the exercise intensity is between moderate and intense; however, at lower velocity. The slow HR increase, which is due to the adrenergic sympathetic activation, is present from the 60 to 90s. This standard, characterized in studies with and without pharmacological block, may suffer age and the level of physical conditioning influence.

Some mathematical approaches may help to characterize and understand the behavior of the HR responses in the rest-exercise transition. Thus, the HR responses modulated by the parasympathetic nervous system may be characterized by calculation of deltas 0-10 and 0-30s (∆0-10s and ∆0-30s), and the responses modulated by the sympathetic nervous system may be characterized both by a delta and linear regression applied to data of the 60-240s interval. While the 60-240s delta (∆60-240s) represents the HR response amplitude, the analysis of the linear regression provides information about the HR adjustment velocity in this period, under predominance of sympathetic modulation.

Due to the easy application of the devices supra-mentioned methods, they were chosen in the evaluation of age influence on the HR responses during dynamic exercise. Thus, the present study is justified by the presentation of a simple methodology for
characterization of the autonomic responses in the rest-exercise transition in two groups of individuals from different age groups. Therefore, the aim of this study was to test the hypothesis that young and middle-aged individuals present different HR responses in exercise of moderate and intense intensity, using values of different response time constants and of a simple linear regression model applied to the data. Additionally, we evaluated the oxygen consumption (O₂) at the moment of the ventilatory anaerobiosis threshold (TAv) and exertion peak of the studied volunteers.

METHODOLOGY

A transversal study approved by the Ethics Committee of the State University of Campinas (Resolution 225/1997). The volunteers were informed about the procedures they were going to be submitted to and signed a free and clarified consent form.

Subjects

The following inclusion criteria were applied: men aged between 19 and 29 years and between 50 and 60 years to compose the groups of young individuals (YG) and middle-aged individuals (MAG), respectively. The volunteers should present sedentary life style, not be smokers, to have absence of any evidence of cardiovascular disease or other abnormalities of the pulmonary, osteo-myarticular or neurological systems. All volunteers were submitted to clinical examinations (anamnesis and physical examination) and laboratory examinations (blood biochemical, hematological, type I urine, conventional rest electrocardiogram and electrocardiogram under exertion) for characterization of their health status. The tests were performed at the same time of the day, with room temperature between 20 and 23 ºC and relative air humidity between 40 and 60%. Before the day of the experiment, the individuals were familiarized with the technicians, procedures and devices to be used.

Procedures

The evaluation procedures were performed in the Exercise Physiology Laboratory of the Physical Education School, Unicamp. The volunteers were told not to ingest alcoholic drinks and/or stimulants nor perform extenuating exercises 24 hours before the test performance. Prior to the data collection, the volunteers were asked to come at the tests days wearing comfortable clothes and foot wear, suitable for physical activity practice. Prior to the data collection, the volunteers were asked about their general health status and quality of sleep at the previous night with the purpose to determine their participation in the procedures.

Protocols of exercise tests

Clinical exercise test

It was performed in a cycle ergometer (Corival 400, Quinton, Seattle, WA, USA) with the aim to evaluate the cardiovascular responses to physical exercise and determine the power increase rate for the cardiopulmonary exercise test (CPET). A conventional electrocardiogram of 12 derivations at rest was performed. Still at rest, and at the end of each stage, the electrocardiographic outlining was recorded (MC5, aVF and V2 derivations) and blood pressure checked (BP) by auscultatory method. The following criteria were applied for test interruption: to reach the expected maximal HR concerning age and/or presence of signs or physical exhaustion symptoms.

Cardiopulmonary exercise test (CPET)

This test had the aim to evaluate the aerobic capacity and power of the volunteers, as well as to identify the response of the cardiovascular, ventilatory and metabolic variables at the moment of the anaerobiosis threshold, identified by the ventilatory method (TAv), and exertion peak. The protocol included a period of three minutes of warm-up with power of four watts (W). The subsequent increments corresponded to 10% of maximal power reached in the clinical exercise test. The TAv was visually identified when the rate of CO₂ release presented non-linear increment concerning the oxygen consumption (VO₂) 1/2. The oxygen consumption (O₂) was picked breath-after-breath through a gas analyzer and metabolic measures (MMC Horizontal System, Sensormedics, Yorba Linda, CA, USA) and their values were expressed in means at every 15s. The HR was recorded beat-after-beat and expressed in mean values at every 10s. At the end of the CPET, before its interruption, the Borg-CR10^3 scale was applied for evaluation of the dyspnea sensation or muscular fatigue.

Exercise test in constant load (ETCL)

The ETCLs were performed with the aim to evaluate the HR behavior in different powers, which ranged from 25 to 150W in 25W intervals. The protocol, performed in cycle ergometer (Corival 400, Quinton, Seattle, WA, USA), consisted of a warm-up phase per one minute in 4W power, followed by the sudden power increment, kept for four minutes, and for one recovery phase in 4W power per minute. There was a recovery period between each ETCL so that the BP and HR values returned to the basal values. This period ranged between 15 and 30 minutes. The HR and the O₂ were recorded during the three phases of the ETCL, while the BP was recorded before the beginning and at the final 30s of the power application. Subsequently, based on the mean O₂ values observed at the final minute of each ETCL concerning the O₂ observed in the TAv identified in the CPET, the isoloads were calculated (moderate and intense exercise). In order to determine the isoloads of moderate and intense exercise, the values corresponding to 50-80% and 110-140% of O₂ in the TAv, respectively, were applied. This procedure was performed so that the HR responses could be compared between subjects, regardless of their physical capacity.

Analysis of the deltas and HR angular coefficient

The following HR deltas were analyzed: a) Δ0-10s, obtained by the HR difference in the 10º s of ETCL and the mean HR of the pre-test 60s so that the amplitude of the vagal removal until the initial 10s could be measured; b) Δ0-30s, obtained by the HR difference in the 30º s of the ETCL and the mean HR of the pre-test 60s in order to measure the amplitude of the vagal removal in the initial 30s; and c) Δ60-240s, obtained by the difference between the HR in the 240º s and HR in the 60º s of the ETCL, in order to measure the amplitude of the HE increment, modulated by the sympathetic nervous system.

A simple linear regression ^11, which uses the square minimum
method for identification of the best parameters of the line adjustment to the HR data behavior of the 60° to 240° s of the ETCL was applied. The equation applied was:

\[ y = \beta x + I \]

Where, \( y \) represents the dependent variable (HR), \( x \) the independent variable (time), \( \beta \) the angular coefficient (i.e., HR increment velocity) and \( I \) is the intersection point of the function with the y axis. The y axis was dislocated in the x axis until the point corresponding to the 60° second (figure 1) for this analysis. The correlation coefficient \( r \) was used to verify the quality of the linear adjustment.

**STATISTICAL ANALYSIS**

The sample calculation was based on the ∆0-10s values of the HR response obtained in a pilot study with four volunteers in each group, assuming \( \beta = 0.8 \) and \( \alpha = 0.05 \) values. The result suggested seven ETCLs and presented according to the analyzed exercise intensity.

**RESULTS**

**Anthropometrical characteristics**

17 volunteers, sorted out in two groups according to age group were evaluated (table 1). Body mass and BMI were higher in the MAG compared to the YG (p < 0.05).

**CPET**

During the cardiopulmonary exercise test (CPET), the groups presented different HR, \( O_2 \) and power values in the moments concerning the TAv and the exertion peak, and the YG presented higher values (table 2). However, the exertion perception evaluated by the Borg scale in the exercise peak, and the percentage values of \( O_2 \), HR and power observed in the TAv moment concerning the exercise peak (Tav/PEAK) were not different between groups. At the rest condition, only the \( O_2 \) was different between groups.

**ETCL**

Table 2 also presented the percentage values of \( O_2 \) applied in the definition of the isoloads corresponding to the moderate and intense exercises. The percentage values correspond to the ratio between the \( O_2 \) observed in the ETCL and the \( O_2 \) observed at the moment of the TAv, identified in the CPET. It can be observed that there was no significant statistical difference between groups, which indicates that the isoloads were equivalent.

Table 3 presents the values of angular coefficient (\( \beta \)), intercept (I) and HE deltas (∆0-10s, ∆0-30s and ∆60-240s) obtained in the ETCLs and presented according to the analyzed exercise intensity. The MAG presented lower I and ∆0-10s values in the moderate and intense exercise, and the \( \beta \) in the moderate exercise when compared with the YG. No significant statistical difference was observed between groups for the ∆0-30s and ∆60-240s values.

Figure 2 presented the intercepts (I) and angular coefficients (\( \beta \)) behavior mediated by the sympathetic autonomous nervous system at the moderate and intense exercise intensities. The linear regression analysis shows that the MAG presents lower intercept values at the two intensities and lower adjustment velocity (\( \beta \)) in the moderate exercise intensity.
Aging, especially after 50 years old 13-15. Such decline may be associated with decrease of HR peak, peripheral blood flow and/or oxygen extraction 2,16.

However, in an attempt to compensate this HR decrease and keep the cardiac debt necessary to a given metabolic demand imposed by the exercise, increase of the systolic volume may occur in the exercise peak (1)11. Thus, the lower peak O₂ values observed in the older age groups seem to play an important role to the mechanisms of oxygen peripheral delivery and extraction 2,19,20, besides the central mechanisms. Since the groups presented similar behavior in the TAv/PEAK ratio for the O₂, HR and power variables (table 2), it can be inferred that the lower O₂ values in the TAv observed in the MAG can also be associated with the HR peripheral blood flow and/or oxygen peripheral extraction² decrease observed consequent of aging²².

ETCL

The HR autonomic modulation is very complex, since its behavior may be influenced by many peripheral afferent stimuli as well as by central mechanisms⁷,10. The concept of the signs of the exercise, regardless of the type of exercise, was widely studied²²,²³ and has been accepted by the scientific community.

In 1986, Maciel et al.⁶ presented a study in which the effects of the pharmacological block of the sympathetic and parasympathetic efferents in the heart rate response of healthy men, and confirmed that tachycardia in the rest-exercise transition presents a biphasic behavior. Initially, tachycardia is vago-dependent⁴,⁷ and is independent from the exertion intensity performed. Subsequently, in moderate or intense exercise, a slow increment phase in the HR response occurs due to the sympathetic activation.

In the present study, the initial tachycardia behavior was investigated by the analysis of the ∆0-10s and ∆0-30s values, in the studied intensities. In the MAG, the lower ∆0-10s values indicate initial amplitude of vagal removal less prominent than the one observed in the YG in this period. On the other hand, the groups did not present difference in the ∆0-30s comparison, which indicates that the YG presents higher vagal removal intensity in the earlier phase of the rest-exercise transition (0-10s) and the MAG in the later phase (10-30s). The decrease of autonomic reflex response capacity suffers influence of aging due to alterations in the baroreflex consequent of the decrease of sensitivity of the peripheral receptors.¹⁰. This mechanism may have led to delay in the HR observed in the earlier phase (∆0-10s) of the rest-exercise transition²³,²⁴ in the MAG.

In moderate exercise, after the period of vagal removal, the activity of the vagus nerve may occur, which leads to decrease in HR before 60⁹ second of exercise ⁶. When this mechanism is present, the determination of the intercept, evaluated from the 60-s-240⁹ second interval, may present lower HR values compared with the ones observed in the 30⁸ second. However, after the period of vagal removal (0-30s) participation of the sympathetic modulation on the HR with the aim to adjust it to the metabolic demand may also be observed. Thus, the HR adjustment in the 30-60s period occurs through two mechanisms of autonomic adjustment⁶.

Our results show that, although there is no significant statistical difference for the ∆0-30s, the intercept values were higher in the YG. Therefore, it can be concluded that this behavior has occurred due to the higher initial vagal contribution (0-10s), which may have

Table 3. Angular coefficient (β), intercept (I) and deltas (∆0-10s, ∆0-30s and ∆60-240s) values observed in the rest-exercise transition in the exercise tests in constant load, in the moderate and intense exercise intensities.

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Variables</th>
<th>YG (n = 10)</th>
<th>MAG (n = 7)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>∆0-10s</td>
<td>β</td>
<td>0.01 (-0.01-0.07)</td>
<td>0.005 (-0.02-0.02)</td>
<td>0.022</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>0.7 (0.6-0.9)</td>
<td>0.7 (0.4-0.8)</td>
<td>0.455</td>
</tr>
<tr>
<td>∆0-30s</td>
<td>β</td>
<td>0.07 (0.02-0.13)</td>
<td>0.06 (0.02-0.11)</td>
<td>0.613</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>0.8 (0.6-0.9)</td>
<td>0.9 (0.8-0.9)</td>
<td>0.142</td>
</tr>
<tr>
<td>∆60-240s</td>
<td>β</td>
<td>0.01 (-0.01-0.07)</td>
<td>0.005 (-0.02-0.02)</td>
<td>0.022</td>
</tr>
</tbody>
</table>

Data expressed in median, minimum and maximum. β: angular coefficient of the line; I: Intercept; ∆0-10s: delta 0-10s; ∆0-30s: delta 0-30s; ∆60-240s: delta 60-240s and R: correlation coefficient of the linear regression. Mann-Whitney test. * = p ≤ 0.05; ** = p ≤ 0.01; *** = p ≤ 0.001.
lasted and influenced on the subsequent responses. Nevertheless, one cannot exclude the possibility of sympathetic contribution in this period.

After the 60° second of moderate or intense exercise, slow HR increment is observed as consequence of the sympathetic contribution on the sinus node6,12. Such behavior, represented by the variables of the 60-240° second interval (β, I, and Δ), has its magnitude temporarily correlated with alterations in the blood lactate concentration7,26-28. Although the magnitude of this contribution (60-240s) had not presented differences between the groups in the exercise intensities studied, the HR adjustment velocity (β) was lower in the MAG during moderate exercise. This result indicates that the MAG presents reduction of velocity of HR adjustment mediated by the sympathetic system after 60 s from the 60° second of moderate exercise. On the other hand, in intense exercise, the HR response in the rest-exercise transition was not different between groups. This behavior may be associated with the greater complexity of the peripheral adjustments necessary to supply the high metabolic demand17,26.

**REFERENCES**


**Clinical implications of the study**

The HR response in the rest-dynamic exercise transition presents differences in relation to aging and may be characterized by simple methods such as linear regression analysis and the deltas analysis. These methods of analysis of the autonomic nervous system on the heart may be easily applied in the clinical practice and its application contributes to better understand the capacity of response to dynamic physical exercise.

**CONCLUSIONS**

The young individuals present vagal removal of greater magnitude in the initial stage of the HR response during dynamic exercise in constant load in the intensities analyzed and higher adjustment velocity of the sympathetic response in moderate exercises.

All authors have declared there is not any potential conflict of interests concerning this article.