ORIGINAL ARTICLE

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

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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[1,2]. 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 parassympathetic 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 [3,4]. After about 30s, decrease in HR derived from the parassympathetic reactivation on the sinusal nodule[5] 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[4]. This standard, characterized in studies with[6-8] and without [9] pharmacological block, may suffer age and the level of physical conditioning influence[10].

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 (Δ0-10s and Δ0-30s)[6,7] and the responses modulated by the sympathetic nervous system may be characterized both by a delta[6,7] and linear regression[11] applied to data of the 60-240s interval[6,7]. While the 60-240s delta (Δ60-240s) 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[11].

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 (O_2) 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, osteomyoarticular 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°C 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 and to have a light meal at least two hours before the test.

The volunteers were instructed to arrive 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 CO_2 release presented non-linear increment concerning the oxygen consumption (VO_2)[1,12].

The oxygen consumption (O_2) 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[13] 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 O_2 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 O_2 vales observed at the final minute of each ETCL concerning the O_2 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 O_2 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 60º to 240º 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), β 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 60º second (figure 1) for this analysis. The correlation coefficient r was used to verify the quality of the linear adjustment.

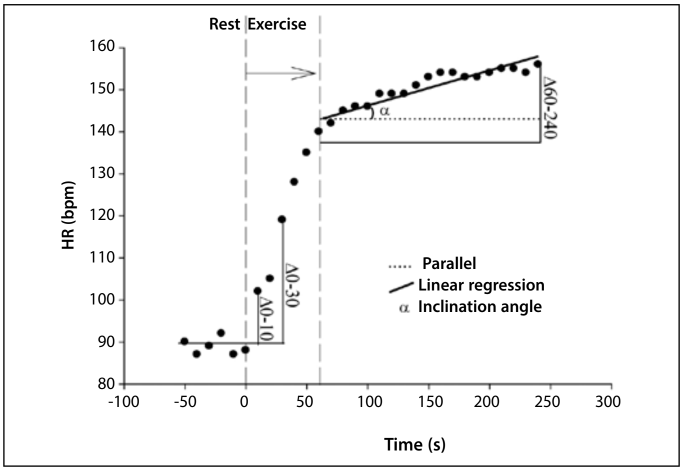

Figure 1. HR response in the rest-exercise transition of one volunteer from YG during one ETCL in the isoload corresponding to the intense exercise. The vagal removal may be characterized by the Δ0-10s and Δ0-30s. Approximately 60s after the beginning of the exercise, the rate and of HR increase derived from the sympathetic activation may be estimated by the angular coefficient β (i.e., tangent of the angle **α**) and by the Δ60-240s, respectively.

STATISTICAL ANALYSIS

The sample calculation was based on the Δ0-10s values of the HR response obtained in a pilot study with four volunteers in each group, assuming β = 0.8 and α = 0.05 values. The result suggested seven volunteers in each group. Considering the sample size and the data distribution, application of non-parametric statistical tests was chosen for the intergroup comparisons. The data are presented in median, minimum and maximum values. The significance level considered was 5%.

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.

Table 1. Age and anthropometric characteristics of the young group (YG) and middle-aged group (MAG).

	YG (n = 10)	MAG (n = 7)	P value
Age (years)	21 (19-27)	52 (50-58)	< 0.001
Anthropometric characteristics			
Body mass (kg)	67 (53-82)	86 (65-96)	0.002
Stature (cm)	174 (166-188)	169 (158-181)	0.732
BMI (kg/m^2)	22.9 (17.9-27.2)	28.5 (26.2-30.5)	0.002

Data expressed in median (minimum and maximum). BMI: body mass index. Mann-Whitney test.

Table 2. Cardiorespiratory variables measured before and during the cardiopulmonary exercise test (CPET) and characterization of exercise intensities in relation to the percentage of the oxygen consumption observed in the anaerobiosis threshold moment (TAV) in the young group (YG) and middle-aged group (MAG).

Variables	YG (n = 10)	MAG (n = 7)	P value
Rest			
O_2 (ml.min^{-1}.kg^{-1})	4.5 (3.3-4.7)	3.8 (3.3-4.3)	0.009
HR (bpm)	88 (81-109)	86 (75-100)	0.930
TAv			
O2 (ml.min^{-1}.kg^{-1})	19 (13-22)	13 (11-18)	< 0.001
HR (bpm)	134 (118-151)	115 (96-127)	< 0.001
Power (W)	106 (42-119)	77 (63-110)	0.003
Peak			
O_2 (ml.min^{-1}.kg^{-1})	36 (32-43)	28 (22-35)	< 0.001
HR (bpm)	191 (168-204)	158 (138-175)	< 0.001
Power (W)	213 (147-253)	171 (151-200)	0.004
Borg scale	9 (8-10)	8 (7-9)	0.362
Tav/PEAK			
O_2 (%)	50 (37-57)	49 (39-57)	0.809
HR (%)	71 (64-81)	72 (67-76)	0.480
Power (%)	48 (28-54)	45 (37-61)	0.873
Isoload			
Moderate (from 50 to 80%)	70 (61-76)	72 (57-78)	0.832
Intense (from 110 to 140%)	129 (114-133)	128 (115-134)	1.000

Data expressed in median, minimum and maximum.. TAv: ventilatory anaerobiosis threshold; HR: heart rate; O_2: oxygen consumption; Isoload: % of the O_2 in the exercise test in constant load concerning the O_2 in the TAv identifed in the CPET. Mann-Whitney test for intergroup comparisons.

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 (β), intercept (I) and HE deltas (Δ0-10s, Δ0-30s and Δ60-240s) obtained in the ETCLs and presented according to the analyzed exercise intensity. The MAG presented lower I and Δ0-10s values in the moderate and intense exercise, and the β in the moderate exercise when compared with the YG. No significant statistical difference was observed between groups for the Δ0-30s and Δ60-240s values.

Figure 2 presented the intercepts (I) and angular coefficients (**β**) 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 (β) in the moderate intensity exercise.

Table 3. Angular coefficient (β), intercept (I) and deltas (Δ0-10s, Δ0-30s and Δ60-240s) values observed in the rest-exercise transition in the exercise tests in constant load, in the moderate and intense exercise intensities.

Intensity	Variables	YG (n = 10)	MAG (n = 7)	P value
	Δ0-10s	20 (10-34)	9 (3-15)	0,009
	Δ0-30s	17 (12-34)	15 (–3-29)	0,570
Moderate	I	23 (12-45)	14 (13-27)	0,050
	β	0,01 (–0,01-0,07)	–0,005 (–0,02-0,02)	0,022
	R	0,7 (0,6-0,9)	0,7 (0,4-0,8)	0,455
	Δ60-240s	2 (–7-8)	0 (–4-6)	0,906
	Δ0-10s	19 (5-37)	11 (1-15)	0,023
	Δ0-30s	27 (14-34)	13 (5-36)	0,056
Intense	I	42 (34-9)	24 (14-44)	0,029
	β	0,07 (0,02-0,13)	0,06 (0,02-0,11)	0,613
	R	0,8 (0,5-0,9)	0,9 (0,8-0,9)	0,142
	Δ60-240s	16 (4-25)	22 (13-24)	0,128

Data expressed in median, minimum and maximum.. β: angular coefficient of the line; I: Intercept; Δ0-10s: delta 0-10s; Δ0-30s: delta 0-30s; Δ60-240s: delta 60-240s and R: correlation coefficient of the linear regression. Mann-Whitney test.

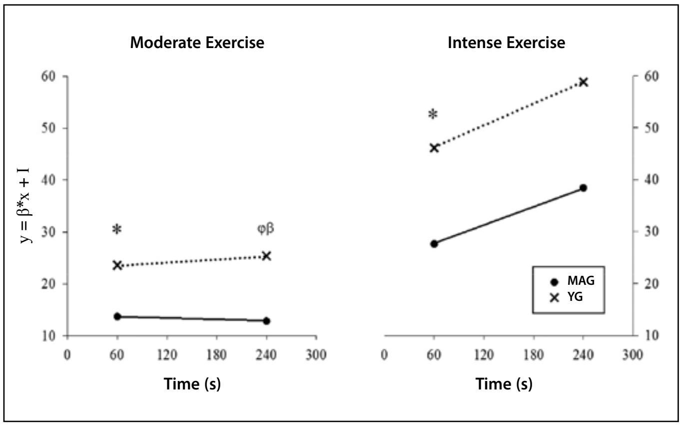

Figure 2. Graphic representation of the HR mean values of the MAG (•) and YG (X), in the moderate and intense exercise intensities. The HR difference between the 60 and 240 corresponds to the Δ60-240. At the y axis, the I values can also be found, which represents the intersection point of the function ($y = β^* x + I$) with the y axis. Mann-Whitney test, * = $p \leq 0.05$; φβ = $p \leq 0.05$ (β)

DISCUSSION

The main findings of the present study were: compared with the YG, the MAG presented lower intercept I and Δ0-10s values in the moderate and intense exercises and lower adjustment velocity (β) at the moderate intensity. No significant statistical difference was found between the Δ0-30s and Δ60-240s values. Additionally, during the CPET, the MAG presented lower values of O_2, HR and power at the TAv and exertion peak moments, characterizing hence lower aerobic capacity and power.

CPET

Several studies associate decline of O_2 at the exercise peak with aging, especially after 50 years old[13-15] .Such decline may be associated with decrease of HR_{peak}, peripheral blood flow and/or oxygen peripheral extraction[2,16].

The HR_{peak} decrease consequent of the aging process, a fact also observed in the present study, associated or not with the peripheral limitations, may result in decrease of the cardiac debt[6,17,18]. 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).(1). Thus, the lower peak O_2 valus 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 O_2, HR and power variables (table 2), it can be inferred that the lower O_2 values in the TAv observed in the MAG can also be associated with the HR, peripheral blood flow and/or oxygen peripheral extraction[2] decrease observed consequent of aging[21].

ETCL

The HR autonomic modulation is very complex, since its behavior may be influenced by many peripheral afferent stimuli as well as by central mechanisms[7,10]. The concept of the signs derived from the upper brain centers, which influence the HR behavior during physical exercise, regardless of the type of exercise, was widely studied[22,23] 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-dependent[4,7] 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 Δ0-10s and Δ0-30s values, in the studied intensities. In the MAG, the lower Δ0-10s 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 Δ0-30s 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 (Δ0-10s) of the rest-exercise transition[23,24] 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 60º second of exercise [6-8]. When this mechanism is present, the determination of the intercept, evaluated from the 60-s240º second interval, may present lower HR values compared with the ones observed in the 30º 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 adjustment[6].

Our results show that, although there is no significant statistical difference for the Δ0-30s, 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 lasted and influenced on the subsequent responses. Nevertheless, one cannot exclude the possibility of sympathetic contribution in this period.

After the 60º second of moderate or intense exercise, slow HR increment is observed as consequence of the sympathetic contribution on the sinusal nodule[6,12]. Such behavior, represented by the variables of the 60-240º second interval (β, I and Δ), has its magnitude temporarily correlated with alterations in the blood lactate concentration[7,26-28]. Although the magnitude of this contribution (Δ60-240s) 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 60º 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 demand[17,26].

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.

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