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Use of predictive equations of maximum heart rate for exercise prescription: a comparative study

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Abstract:
Aim: *The aim of this study was to compare the heart rate peak obtained in a graded exercise test with values obtained by different predictive equations in young adults.*
Methodology: *16 physically active young adult men (24,4 ± 2,7 age) performed a maximal exercise test to determine their peak of Heart Rate (HRpeak). To determine the age-predicted HRpeak, was used the equation attributed to Karvonen et al. "220-age" and the equations proposed by Tanaka et al. "208 - (0,7 x age)" and Jones & Campbell "210 – (0,65 x age)". Repeated measures ANOVA with Tukey's post hoc test were used to compare measured HRpeak with age-predicted HRpeak. Pearson correlation coefficients were used to test the relationships between measured and age-predicted HRpeak to age. Significance was set at p < 0,05.*
Results: *Significant differences were observed between the measured HRpeak and the 220-age equation (p < 0,01), while it was not observed in comparison with Tanaka and Jones equations (p > 0,05). The relationship between measured HRpeak to age showed a moderate and inverse correlation (r = - 0,62; p < 0,01).*
Conclusion: *All age-predicted equations used tended to overestimate the measured value of HRpeak, however only the 220-age equation showed significant difference, demonstrating to be inappropriate for predicting maximal exertion in young adults, and the Tanaka et al. equation showed the best accuracy in terms of predicting HRpeak.*
Keywords: *Exercise prescription, heart rate, prediction equation.*

I. Introduction

One of the most physiological parameters used to assess and control the training intensity is the Heart Rate (HR). In fact, the HR is an easy measuring parameter and provides a good estimate of the effort expended. However, for the same load, we can obtain different heart rate values in different individuals. Thus, it is important to determine the heart rate peak (HRpeak), since most training programs use a certain percentage of HRpeak (%HRpeak), which is individual [1].

In tests to determine HRpeak, it is known that there may be influenced by factors such as the protocol used, type of ergometer [2], time of testing [3] and from the ambient [4]. The treadmill seems to be the most recommended ergometer to determine the HRpeak in laboratory because, besides having a good accuracy, the chance to promote peripheral fatigue is far more delayed when compared to a cycle ergometer test [5-7].

The determination of HRpeak may be impaired in some cases by the costs of the methodology used and bring discomfort and problems concerning the inability to perform the required protocol. Aware of the difficulties in determining the HRpeak, the literature presents several prediction equations that are influenced by age [8].

Among the equations to estimate HRpeak, the most prominent to be widely known and most widely used is the "220 - age", attributed to Karvonen et al. [9]. Even with studies demonstrating that this equation tends to overestimate the HRpeak in young adults [10, 11], organizations such as Brazilian Society of Diabetes [12], Brazilian Society of Cardiology [13] and the American College of Sports Medicine [14] still recommend the equation to determine loads in aerobic exercises.

There are two other equations that are worth mentioning, which are proposed by Tanaka et al. [10] "208 - (0,7 x age)" and Jones & Campbell [15] "210 – (0,65 x age)" which, as well as 220-age, can be used regardless of gender. The main characteristic of these HRpeak predictive equations is that all considered this variable decreases with age. Researches explain that it is due to a lower autonomic activity from aging. However, there is in the literature evidence of large margin of error and existence of conflicts in determining the HRpeak between the equations proposed by Karvonen et al. [9], Tanaka et al. [10] and Jones & Campbell [15]. Thus, one perceives the importance of knowledge about the estimated HRpeak to apply it during the assembly training programs.

Accordingly, the aim of the present study was to compare the heart rate peak obtained in a graded exercise test with values obtained by different predictive equations in young adult men.

II. Material and Methods

2.1 Subjects

The study enrolled 16 young adult men (24.4 ± 2.7 age), physically active and apparently healthy. Inclusion criteria included subjects who reported accumulate at least 150 min or more per week of self-reported activity at moderate or high intensity, aged between 20 and 40 years old, nonsmokers, with no history of chronic disease and who have not used drugs that affect cardiac function.

The subjects were recruited for this study by invitation from an invitation letter and before participation, the subjects gave their written informed consent to participate in this investigation. The research protocol of this study was in accordance with the Declaration of Helsinki and approved by the Ethics Committee on Human Research of the State University of Rio Grande do Norte.

2.2 Procedures

2.2.1 Maximal exercise test

The maximal exercise test was performed on a treadmill Centurion 300 (MICROMED, Brasília, DF). Prior to the maximal testing, all participants carried out a warm-up period of 10 min at an individualized treadmill speed. After heating, the test started at a speed of 4 km/h and inclination of 1%. The stages had a duration of 1 minute, at the end of each stage the speed was increased by 1 km/h until maximum voluntary fatigue of the individual. The slope was maintained at 1.0% to simulate air resistance in external environment and to the peripheral fatigue does not influence the test. The relative humidity (60.0%) and temperature (22ºC) were monitored during the test. Heart rate was monitored continuously by radio telemetry (Polar RS800cx, Polar Electro Oy, Kempele, Finland) and at the end of each stage the value was registered. HRpeak was defined as the highest value recorded during the test; however the participants were verbally encouraged to stay as long as possible in exercise.

2.2.2 Anthropometric measures

Body mass (kg) was determined using a portable electronic digital scale TANITA® (Ironman BC 553, Tokyo, Japan) with an accuracy of 0.100 kg. Height was measured using a SANNY® (Personal Portable Caprice, Brazil) stadiometer with an accuracy of 0.1 cm. Body mass index (BMI) calculation was determined by the ratio of body mass by the square of height ($kg \cdot m^{-2}$).

2.3 Statistical analysis

All statistical analyses were performed with the use of BioEstat (5.0, Belém, PA, Brazil). The normality of the data was verified by the Shapiro-Wilk test and data are presented as mean±SD. Repeated measures ANOVA with Tukey's post hoc test were used to compare mean HRpeak measured during the graded exercise treadmill test and the mean HRpeak predicted by the equations highlighted above. Pearson correlation coefficients were used to test the relationships between measured and age-predicted HRpeak to age. Significance was set at $p \leq 0.05$.

III. Results

The basic characteristics of the subjects can be found in Table 1.

Table 1. Participant's characteristics.

Variables	Mean	SD	Min	Max
Age (years)	24.4	±2.7	21.0	31.0
Weight (kg)	79.2	±6.5	68.0	91.0
Height (cm)	176.1	±3.3	169.0	181.0
BMI (kg/m²)	25.6	±1.6	22.9	28.1
HRrest	66.38	±3.81	59.0	73.0
SBP	118.94	±5.31	105.0	126.0
DBP	78.06	±2.41	74.0	82.0

Legend: Values are presented as mean ± standard deviation. minimum and maximum. BMI= Body Mass Index; HRrest= Rest Heart Rate; SBP= Systolic Blood Pressure; DBP= Diastolic Blood Pressure.

Table 2 presents the heart rate peak values compared to "220-age". "208 - (0.7 x age)" and "210 - (0.65 x age)" equations. Both 220-age. Tanaka et al. equation and Jones et al. equation over predicted HRpeak obtained on the graded exercise test. Repeated measures ANOVA revealed significant differences between the measured HRpeak and the 220-age equation ($p < 0.01$), while in comparison with Tanaka and Jones equations were not found significant differences ($p > 0.05$).

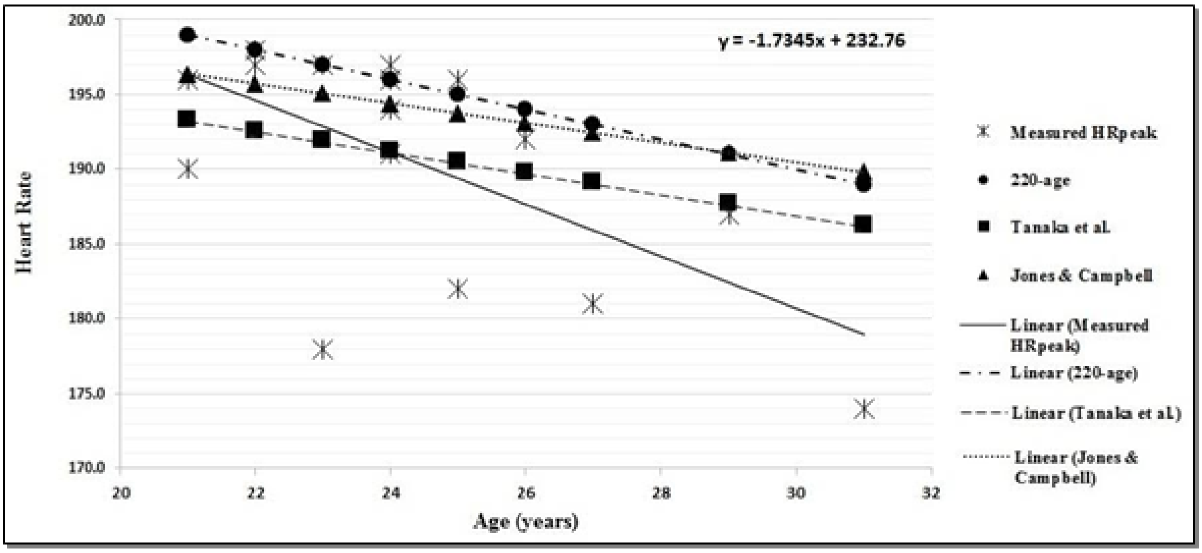
Table 2. Measured HRpeak and estimated HRpeak by different equations in young adult men.

N	HRpeak	220 - age	Tanaka et al.	Jones et al.
16	190.3 ± 7.7	195.5 ± 2.7$^{\Omega\Psi}$	190.8 ± 1.9	193.8 ± 1.6

Values are shown as mean ± standard deviation. $^{\Omega}$ = Significant difference ($p < 0.01$) compared to the value obtained from the treadmill test (HRpeak). $^{\Psi}$ = Significant difference ($p < 0.01$) compared to the value obtained from the Tanaka et al. equation

Figure 1 illustrates a decline in HRpeak with increasing age. The regression equation for HRpeak resulted from the sample was y = -1.7345x + 232.76 and measured HRpeak was moderate and inversely related to age (r = - 0.62; $p < 0.01$).

Figure 1. – Individual values and regression lines depicting the relation between measured and predicted HRpeak with age.



IV. Discussion

The present investigation compared the estimated HRpeak obtained through three different equations with the real value obtained in a maximum effort test in young male adults. After data analysis, it was observed that all three equations tended to overestimate the subjects maximum capacity.

Were used the equations proposed by Tanaka et al. [10], Jones & Campbell [15] and the "220-age", atributed to Karvonen et al. [9]. It is worth noting that in a previous investigation, Robergs & Landwehr [16] concluded that the 220-age equation was not developed after original research, but resulted from observation based on data from approximately 11 references consisting of published and unpublished researchs. Gulati et al. [17] reported that this equation was the result of a review conducted by Fox & Haskell [18], based in 10 studies with men, where no one was older than 65 years, with no exclusion based on beta-blockers use and some individuals with established cardiovascular disease, factors that can affect HRpeak response to exercise. Consequently, this formula has no scientific merit for use in the fields related to exercise physiology.

Nonetheless, the Brazilian Society of Cardiology [13] still recommends the use of this equation to pre-determine the HRpeak when performing submaximal tests at 85.0% of the maximum capacity of the subjects, even though there is a risk of not detecting much of cardiac disorders [19].

In the validation study of the of Tanaka et al. [10] equation obtained through a regression analyses, age was strongly related to the maximum heart rate (r = -0.90). Comparing the regression equation with 220-age equation, we observed that the 220-age equation tended to overestimate HRpeak in young adults. For example, at age 20 years, the difference between the two equations was ~6 bpm and ate age 30 years was ~7 bpm. In the present study, these differences were ~4.7 bpm between 220-age and Tanaka et al.10 equations, ~1.7 bpm between the 220-age and Jones & Campbell [15] equations and ~3 bpm between the equations proposed by Tanaka et al. [10] and Jones & Campbell [15].

The Tanaka et al. equation performed the best in terms of predicting mean HRpeak values for young adults. The equation has been suggested for use in the general population [20]. Thus, health care practitioners may choose the ideal equation depending on the physical fitness, gender, age and health status in order to guide better exercise prescriptions. Similar results were found by Franckowiak et al. [21] when comparing three different HRpeak prediction equations in young adults, where the 220-age equation and the Miller et al. [22] equation "200 – 0,48 × age" overestimated the real value, while only the equation of Tanaka et al. showed better accuracy.

Comparing both the 220-age and the Tanaka et al. equations, Morales [23] verified that the 220-age equation was significantly higher than the real value obtained in the graded exercise (p=0,025). On the other hand, the equation presented by Tanaka et al. [10] yield better results, at lower error rate, demonstrating to be best suited when applied to young adults, regardless of gender. Thus, it can be said that the 220-age equation tends to overestimate the HRpeak of young adults. The findings of Tanaka et al. and of the present study lead us to question the use of 220-age equation.

Policarpo et al. [24] performed a comparison with the same equations used in the present study and verified a low correlation between them with the HRpeak, however only the equation proposed by Tanaka et al. did not show significant difference to overestimate the real HRpeak value. On the other hand, in the Araújo et al. [25] study, the Jones et al. equation was the one that presented the best correlation to HRpeak.

HRpeak can be influenced by physiological factors. Among them, the most influential are the physiological changes accompanied by the increase in age, which has a reverse relation with HRpeak. Therefore, as age encreases, HRpeak decreases. This drop in HRpeak probably results from a reduction of sympathetic stimulus derived from the bulb and to changes related to the age in the inherent characteristics of the sinoatrial node [26]. Additionaly, Tanaka et al. [10] found that the rate of decline in HRpeak is primarily due to a reduction in intrinsic heart rate with increasing age.

Attaining an accurate HRpeak is of important clinical relevance for prescribing an adequate exercise intensity for young adults. Regardless of physical activity status, exercise prescriptions for all individuals are designed to optimize both training response and safety. Identifying an accurate percentage of HRpeak improves the chance of optimizing fitness, which could possibly have implications for improvements in exercise adherence [27].

Furthermore, accurate estimations of %HRpeak can also serve as an important indicator to track fitness improvements, whereby clinicians can evaluate improvements in fitness over time when the individuals are able to exercise at a lower percentage of HRpeak for fixed exercise workloads [1].

V. Conclusion

In summary, our findings demonstrated some differences between measured HRpeak and estimated HRpeak from different prediction equations. Both 220–age, Tanaka et al. and Jones et al. equations over predicted HRpeak, however only the 220-age equation showed significant difference to the real HRpeak. Despite were not found significant differences for the other two equations, the Tanaka et al. equation demonstrated a more accurate estimated HRpeak among young adult males.

Our results suggest that, in the inability to directly evaluate the maximum capacity of young adult men, the equation proposed by Tanaka et al. can provide better predictions of maximum effort and thus make the exercise prescription more accurate for this population.

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