Original Article

Comparison of Maximal Heart Rate Using the Prediction Equations Proposed by Karvonen and Tanaka

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Summary

Background: Equations for predicting maximal heart rate (HRmax) are widely used in exercise testing and for training prescription, but their efficacy remains controversial in the literature.

Objective: To compare maximal heart rate during cardiopulmonary exercise testing (CPET) using the prediction equations developed by Karvonen and Tanaka.

Methods: Of the 24,120 maximal treadmill graded exercise tests stored in the CEMAFE database from 1994 to 2006, 2047 HRmax values were analyzed, 1091 of which were from male and 956 from female sedentary subjects. These data were used as a gold standard to compare Karvonen's and Tanaka's prediction formulas.

Results: Mean measured maximal heart rates were 181.0 ± 14.0; 180.6 ± 13.0, and 180.8 ± 13.8 for men, women, and both genders combined, respectively. Likewise, mean values from Karvonen's equation were 182.0 ± 11.4; 183.7 ± 11.5, and 183.9 ± 11.7; and from Tanaka's, 182.0 ± 8.0; 182.6 ± 8.0, and 182.7 ± 8.2. Karvonen's and Tanaka's equations yielded the same correlation coefficients, as compared with measured maximal heart rate (r = 0.72).

Conclusion: Karvonen's and Tanaka's equations are similar in predicting maximal heart rate and show good correlation with measured maximal heart rate. (Arq Bras Cardiol 2008; 91(5) : 285-288)

Key words: Heart rate; exercise test; cross-sectional studies.

Introduction

Maximal heart rate (HRmax) is the highest heart rate a subject can achieve in an all-effort to the point of exhaustion[1], being an important physiological variable for assessing maximal exertion during an exercise test[2]. It is widely used for prescribing exercise intensity in aerobic training programs, since it is closely related to maximal oxygen uptake[3]. HRmax is usually higher in untrained than in trained subjects[4]. However, some authors claim that HRmax does not change significantly with training[5]. HRmax reduction with training is probably due to adaptive responses in the heart and autonomic nervous system to achieve an optimal cardiac output[6]. At maximal exercise, HRmax is 5% to 10% lower on a cycle ergometer than on a treadmill, an effect that can be explained by peripheral fatigue[7]. Nevertheless, another study found a good association between measured HRmax using a treadmill and cycle ergometer in 57% of the patients[8]. One of the most commonly used HRmax prediction equations is the 220 – age formula[9], proposed by Fox et al[10]. This equation tends to overestimate HRmax in young subjects (< 40 years) and underestimate HRmax in older subjects[11]. Another equation used to predict HRmax is the regression model proposed by Tanaka et al[12], the 208 – (0.7 x age) formula, which yields lower values than Karvonen et al[9]. These equations may allow large margins of error[3]. The literature is controversial regarding the use of HRmax prediction equations; some studies show a good correlation between measured and predicted HRmax, while in others this correlation is weak. This may be partly attributed to variations in experimental conditions, such as the type of population, small sample size, and different evaluation protocols, equipment for analysis, and ergometer used.

This study was designed to compare HRmax, as determined by maximal treadmill cardiopulmonary exercise testing, in male and female sedentary Brazilians, ages ranging from 12 to 69, using the prediction formulas developed by Tanaka et al[12] and Karvonen et al[9].

Methods

This was a retrospective, cross-sectional study conducted at the Centro de Medicina da Atividade Física e do Esporte (CEMAFE) of the Universidade Federal de São Paulo, Escola Paulista de Medicina. The study protocol was approved by the

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Institutional Research Ethics Committee under No.0961/06. Of the 24,120 maximal treadmill graded exercise tests stored in the CEMAFE database from 1994 to 2006, 2047 HRmax values were analyzed, 1091 from male and 956 from female sedentary subjects. These data were used as a gold standard to compare the prediction formulas proposed by Karvonen and Tanaka. After all data were tabulated, maximal heart rates were estimated using Karvonen's (220-age) and Tanaka's (208 - [0.7 x age]) equations and compared with measured HRmax. Sedentary but apparently healthy Brazilians, ages ranging from 12 to 69 years, body mass index ≤ 40 Kg/m^2, who underwent treadmill cardiopulmonary exercise testing were eligible for the study. Based on the data derived from the standard CEMAFE questionnaire on lifestyle habits, subjects were considered sedentary if they reported no physical activity at all or less than 20 minutes of physical activity per day less than three times a week for at least the past six months. Subjects, who came to CEMAFE for specific purposes, were asymptomatic and apparently healthy. The individuals considered to be Brazilians were those who declared on their registration cards to have been born in Brazil, thus excluding foreigners and/or naturalized Brazilians.

All cardiopulmonary exercise tests were performed on a treadmill (PRECOR C964i USA) according to a graded protocol for sedentary subjects developed by CEMAFE, which consists of a two-minute stage at 1.8 mph and 0% grade followed by one-minute stages with 0.6 mph increments between them until exhaustion. When necessary, after 10 minutes of increasing workload, treadmill grade was raised 2.5% or 5.0 % every minute. Criteria for terminating the test and classifying it a maximal effort were the following: a plateau in maximal oxygen consumption, a respiratory exchange ratio equal to or greater than 1.1, and exhaustion. Maximum heart rate was measured using ERGO-S ergometry system and EP-3 DIXTAL cardiograph, Brazil. To compare maximal heart rates using prediction formulas, Pearson's correlation coefficient and Student's paired *t*-test were used[13]. Means and standard deviations were determined for weight, height, body mass index, age, and maximal heart rate during cardiopulmonary exercise testing. As this was a retrospective clinical trial, a major limitation of the study was that the investigator had no control over the tests and questionnaires administered from 1994 to 2006.

Results

Body height (cm), weight (kg), body mass index (kg/m^2), and age were all obtained. These data are presented as means and standard deviations in Table 1. Mean measured HRmax and predicted HRmax using Karvonen's and Tanaka's equations are descriptively shown in Table 2. Using a Student's paired *t*-test, a statistically significant difference was found between measured and predicted HRmax ($p < 0.000$). Pearson's correlation was calculated between measured and predicted HRmax values. Karvonen's (Graph 1) and Tanaka's (Graph 2) equations yielded the same correlation coefficient, as compared with measured HRmax ($r = 0.72$ and $r^2 = 0.52$).

Discussion

Maximal heart rate prediction equations are commonly used in exercise testing and training prescription. The most common formula is 220 - age, probably because it is often cited in textbooks and papers on exercise physiology, included in certification examinations in sports medicine, and used in fitness programs and the fitness industry[14]. However, it has been criticized in the medical literature, since the study from which it was generated was not designed to develop HRmax prediction equations[11]. Therefore, the 220-age formula has no scientific merit for use in exercise physiology and related sciences[3]. According to Tanaka et al[12], the 220 – age[9] formula was first described in a literature review by Fox et al[10], being determined arbitrarily from a total of 10 studies in which the highest age was 65 years and most patients were 55 years or younger. These authors compared the 220 – age[9] and 208 – (0.7 x age)[12] equations and concluded that the first overestimates HRmax in young adults, and that this relationship tends to increase with increasing age. They also noted that these studies included subjects with cardiovascular disease who smoked or were taking cardioactive drugs, conditions that influence HRmax regardless of age[14]. Despite perceptions that the 220 – age equation is inappropriate for use in the health sciences field, the American College of Sports Medicine[15] recommends that Karvonen's formula be used for prescribing aerobic exercise, since it is directly correlated with maximal oxygen uptake.

Our study compared heart rate measured during cardiopulmonary exercise testing, using Karvonen et al[9] and Tanaka et al[12] equations, to establish a correlation between measured HRmax and said prediction formulas. Sample population comprised 2047 sedentary Brazilians, 1091 male and 956 female, ages ranging from 12 to 69. Pearson's correlations between measured HRmax and the equations proposed by Karvonen et al[9] and Tanaka et al[12] were found to be the same ($r = 0.72$). This finding was similar to that reported by Tanaka, who found a correlation of 0.79 for male patients and 0.73 for female patients between measured HRmax and the 208 – (0.7 x age) formula[12]. In a study of elderly women

Table 1 - Sample characteristics based on number of participants (n), age, height, weight, and body mass index (n = 2047).

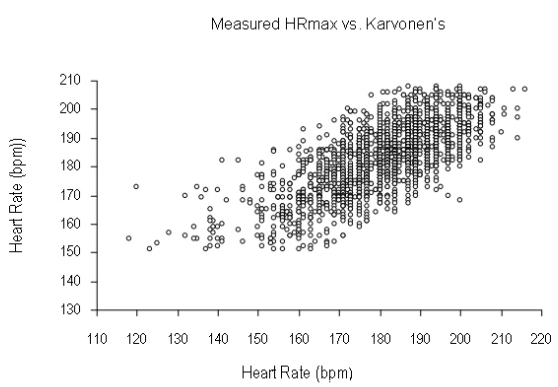
Gender	n	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m2
Male	1091	37.8 ± 11.4	174.9 ± 7.0	82.0 ± 13	26.8 ± 3.8
Female	956	36.3 ± 11.4	161.7 ± 6.8	63.2 ± 10.9	24.2 ± 4.0
Male and Female	2047	37.1 ± 11.4	168.7 ± 9.5	73.3 ± 15.4	25.6 ± 4.1

Values expressed as mean ± standard deviation.

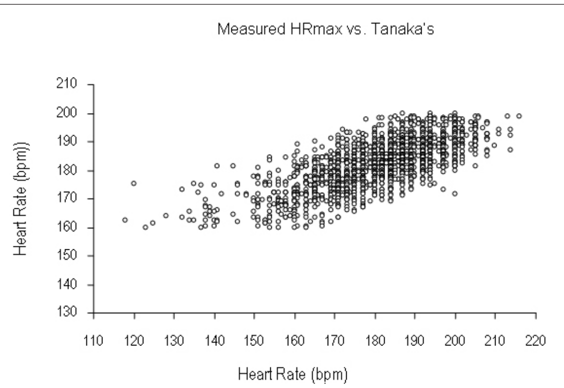
Table 2 - Number of participants (n), statistical analysis (Student's paired *t*-test) between measured maximal heart rate (HRmax) *vs.* HRmax predicted by Karvonen's equation and measured HRmax *vs.* HRmax predicted by Tanaka's equation. HRmax in beats per minute (bpm) (n=2047).

Gender	n	Measured HRmax (bpm)	HRmax (Karvonen) (bpm)	HRmax (Tanaka) (bpm)
Male	1091	181.0 ± 14.0	182.0 ± 11.4*	182.0 ± 8.0**
Female	956	180.6 ± 13.0	183.7 ± 11.5*	182.6 ± 8.0**
Male and Female	2047	180.8 ± 13.8	183.9 ± 11.7*	182.7 ± 8.2**

*Values expressed as mean ± standard deviation; * Student's paired t-test; measured HRmax vs. Karvonen's HRmax t = -9.63 (p < 0.000); * Student's paired t-test; measured HRmax vs. Tanaka's HRmax; t = -5.56 (p < 0.000).*



Graphic 1 - *Pearson's correlation coefficient between measured maximal heart rate (HRmax) and Karvonen's prediction equation "220 – age", (r = 0.72; r = 0.52; n = 2047).*



Graphic 2 - *Pearson's correlation coefficient between measured maximal heart rate (HRmax) and Tanaka's prediction equation "208 – 0.7 x age", (r = 0.72; r = 0.52; n = 2047).*

(60 to 81 years), HRmax values using the prediction equations proposed by Karvonen et al[9] (220 – age) and Tanaka et al[12] (208 – [0.7 x age]) were significantly higher than those obtained during graded exercise testing. A weak correlation was found between measured HRmax and that estimated by Karvonen's (0.354) and Tanaka's (0.342) formulas. However, in the age range of our study sample (12-69 years), measured HRmax values were significantly lower ($p < 0.000$) than those of prediction equations.In subjects with poor fitness level, the use of regressions to indirectly estimate HRmax on a cycle ergometer potentially increases prediction errors and thereby exercise intensity, suggesting that HRmax should be measured directly for each subject[8]. The good correlation found in our study (r = 0.72) between measured HRmax and that estimated by Karvonen's and Tanaka's prediction equations may be explained by the greater number of patients and also by the fact that the tests were performed on a treadmill, rather than on a bicycle ergometer[16]. In a study comparing measured HRmax with that derived from prediction equations, Vasconcelos[17] postulated that the 220 – age formula[9] is more correlated with measured HRmax than that proposed by Inbar et al[18]. This finding contradicts other studies claiming that Inbar et al[18] equation is one of the most accurate[18].

Although indirect methods of measurement are more effective in determining HRmax, prediction formulas, particularly the 220 – age equation, are still commonly used by health care professionals. Our study has shown that measured HRmax correlates well with prediction equations. Nonetheless, further studies are needed to develop more accurate equations for estimating HRmax. We believe that the sample size and data collected at the Centro de Medicina da Atividade Física e do Esporte (CEMAFE) enable this study to compare measured HRmax with those based on the prediction equations proposed by Karvonen (220 – age) and Tanaka [208 - (0.7 x age)].

Conclusions

The prediction equations proposed by Karvonen (220 – age) and Tanaka (208 - 0.7 x age) are similar in estimating HRmax in male and female subjects 12 to 69 years old, showing good correlation (r = 0.72) with measured HRmax.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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There were no external funding sources for this study.

Study Association

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