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Research Article

Correlation and Difference between the Maximum Cardiac Frequency and the Formulas of Tanaka and 220-Age

Pereira-Rodríguez Javier Eliecer[1]*, Quintero-Gómez Juan Camilo[2], Sánchez Cashier Oscar Alejandro[2], Hernandez-Sanchez José Luis[2], Lopez-Dichi JackeliNe[2], Mauricio Reynoso Roberto Aldair[2], Serrano-Richard's Mauricio Alfonso[2] and Solorzano-Velasco Alejandro[2]

[1]Physiotherapist, Specialist in Cardiopulmonary Rehabilitation, Teacher in Health sciences, Teacher in Educational Innovation, University Teacher, Puebla, Mexico

[2]Student of Physiotherapy, Puebla, Mexico

***Corresponding Author:** Pereira-Rodríguez Javier Eliecer, Physiotherapist, Specialist in Cardiopulmonary Rehabilitation, Teacher in Health sciences, Teacher in Educational Innovation, University Teacher, Puebla, Mexico.

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Abstract

Introduction and Objective: The exercise prescription is intended to increase the level of physical activity and the maximum heart rate is usually used to compute training heart rates. The objective is to determine the differences between the results of the equations for FCM and an effort test according to the Bruce protocol.

Materials and Methods: Observational, descriptive and cross-sectional study with 300 participants of average age of 26 ± 10 years. Anthropometry, vital signs, Borg scale, questionnaire for risk factors and exercise test were obtained. In addition, it was analyzed by means of ANOVA, post hoc test by Tukey test. Likewise, the variables were correlated using the Pearson R.

Results: The FCM by stress test in the 300 participants was 179.6 ± 15 beats per minute. In the formulas was observed a overestimation for 220-Age (193 ± 10.48, 14 bpm, p = 0.000); like Tanaka (189 ± 7.6; 9 bpm; p = 0.000). And regarding the Pearson´s r for 220-Age it was r = 0.447 and Tanaka r = 0.451.

Conclusions: The equations evaluated are not recommended due to their significant differences with respect to the maximum stress test; In addition, they did not present a strong positive correlation and showed differences of mean above 14 beats per minute.

Keywords: *Heart Rate; Training; Stress Test; Prescription of the Exercise*

Introduction

Heart rate (HR) is defined as the number of heart beats per minute and according to Kent., *et al.* (2003), the maximum heart rate is the maximum value of the heart rate obtainable during a supreme effort to the edge of exhaustion [1]. HR is a variable of the functioning of the cardiovascular system having implications on cardiac output and myocardial oxygen consumption [2].

However, the FC is used to establish maximum workloads taking into account factors such as temperature, trophism, physical state, among others, which modify their values, but can be controlled by following the FC [3]. This is a basic parameter of cardiovascular physiology because it is a fundamental determinant of endothelial function, cardiac output and coronary blood flow [1].

The maximum heart rate (HR_{max}) is often used to compute training heart rates and can be determined directly by using maximum workloads, but it is not always a safe or practical procedure. Due to the above, equations are usually used to approximate these theoretical values [2-4].

Therefore, there are many ways to control the intensity of exercise such as scales and laboratory tests, but FC is used because of its easy handling and obtaining procedure. In addition, the existing relationship between the HR_{max} and VO_2 max that allow better control over training loads [5,6].

On the other hand, the stress test (PE) is used to determine non-invasively the effect of exercise on the heart by subjecting it to physical stress. For this procedure, we found multiple models of protocols to determine HR_{max} [7]. PE can be considered maximum or submaximal depending on the intensity of the exercise. The maximum stress tests are established when the patient reaches the maximum capacity of the effort or the theoretical HR_{max}, and the submaximal stress test develops when 85% of the HR_{max} is reached. theoretical The protocols of the PE that are most used are on the cycle ergometer and treadmill (Bruce, modified Bruce, Naughton, ACIP, Blake) [8].

In such a way, that the HR_{max} is used as a parameter for the prescription of physical exercise as a criterion to frame limits in the development of aerobic activity [9]. The maximum heart rate is a variable that allows us to obtain data to evaluate and prescribe physical exercise. They can be identified by two mechanisms; the heart rate after a high intensity effort [10-12] and using statistical models that approximate the real values [13].

Tanaka., *et al.* (1997), in a study with 156 women segmented into two groups (female athletes and sedentary women), with an average age range of 21 - 73 and 20 - 75 respectively; The maximum heart rate was arbitrarily underestimated, taking into account that age was found to be inversely proportional to the aerobic capacity and the maximum oxygen consumption value (VO_2 max) [14,15].

Also, it has been found that it is necessary to take into account that a statistical equation should not be used in a generalized manner, since it is necessary that there be a specificity about the physiology of the individual [16,17]. Different studies have rejected the use of statistical models to determine HR_{max} and suggest making laboratory tests to monitor and predict maximum heart rate [10,18-23].

Many investigations [19,24-26] suggest some types of statistical models to determine the HR_{max}, but there is no specific guideline, there is too much variability and even, differences of beats on the values in the stress test. PE is performed so that these models have sufficient validity and reproducibility, in addition to which they must be individualized according to the patient's resistance [11]. However, In 2001, Tanaka., *et al.* published in the Journal of the American College of Cardiology a study suggesting the use of a new equation [208.75 - (0.73 x age)]; which, would be the most accurate to evaluate this parameter. Therefore, given the frequency with which these formulas are used and the great usefulness of it, the main objective of the present investigation arises: To determine which of these equations has the highest correlation between the HR_{max} reached by the patient versus the expected HR_{max}, according to the formulas of 220-Age, 210-Age and the formulas of Tanaka.

Materials and Methods

An observational, descriptive and cross-sectional study was carried out that quantified the cardiovascular risk, the maximum heart rate obtained through a stress test and theoretical equations in a population of 300 (181 Women and 119 Men) participants with an average age of 26 ± 10 years of the city of Cúcuta, Colombia. Participants must be over 18 years of age, apparently healthy, and sign an informed consent endorsed by the ethics committee of the institution. Participants with pain in the lower limbs, dyspnea and/or fatigue greater than 3, individuals with cardiovascular alterations or surgical history of cardiovascular type or acute myocardial infarction were excluded. As withdrawal criteria, hemodynamic instability during the test and the manifestation of not wanting to continue were taken into account.

Data collection

For the collection of sociodemographic data an instrument was used, which was completed by questioning the patient. To find the morphological, anthropometric and vitale signs; Adult Acrylic Halter Wall Kramer 2104 (stadiometer), Asmico 150 cm 60'' Gree (tape measure), Balance Tezzio Digital Balance TB-30037 (electric bioimpedance), Nellcor Puritan Bennett (portable pulse oximeter). In addition, the Z score (Z-score) was obtained for the BMI (kg/m^2) through Excel, developed based on the WHO reference. The Z score of the BMI allowed grouping the sample into underweight, normal weight, overweight and obesity.

The stress test was performed in an endless band with the Bruce protocol (Table 1), patients could not drink, smoke or consume any type of drug or medication that could interfere with the HR_{max}. The perceived dyspnea and the effort were assessed using the modified Borg scale. The Borg Scale of Perceived Exertion [27] consists of 10 indicators of the effort perceived by the individual, initially against the exercise, currently used at other times. Its use in the area of health sciences is given for intensity adjustments and/or workloads.

Stages	Time (Total)	Speed	Pending (%)	METS (Approx.)
1	3 Minutes (3 Min.)	2.7 km/h	10	4.7
2	3 Minutes (6 Min.)	4.0 km/h	12	6.8
3	3 Minutes (9 Min.)	5.4 km/h	14	9.1
4	3 minutes (12 Min.)	6.7 km/h	16	12.9
5	3 Minutes (15 Min.)	8.0 km/h	18	15
6	3 Minutes (18 Min.)	8.8 km/h	20	16.9
7	3 Minutes (21 Min.)	9.6 km/h	22	19.1

***Table 1.** Bruce protocol in endless band.*

METS: Metabolic Equivalent of Task - Unit of measurement of the metabolic index and corresponds to 3.5 ml O_2/kg x min.

The heart rate was obtained by the Polar RS800CX Multisport system, while arterial oxygen saturation with a portable pulse oximeter (Nellcor Puritan Bennett); These measurements were taken pre, peri and post stress test. Regarding blood pressure, this was obtained manually at the beginning, end and after 5 minutes of having completed the stress test.

The value of the HR_{max} obtained after a maximum effort was considered as a dependent variable (result). As independent variables (predictors) were taken the Tanaka equations and the famous formula 220-Age and 210-Age (Table 2).

#	Study	Formula
1	Tanaka., *et al.* (1997)	211-0,8*Year
2	Tanaka., *et al.* (2001)	207-0,7*Year
3	Tanaka., *et al.* (2001)	206-0,7*Year
4	Tanaka., *et al.* (2001)	208,75-0,73*Year
5		220-Year
6		210-Year

***Table 2:** Equations for calculation of maximum cardiac frequency.*

The design and development of the research was carried out under the ethical considerations of the Declaration of Helsinki and Resolution No. 008430 of the Ministry of Health of Colombia.

Statistical Analysis

For the description of the quantitative variables, it was necessary to express them as arithmetic mean and standard deviation. Regarding the comparison of the HR_{max} between the theoretical equations versus the one obtained in the stress test, it was carried out by means of ANOVA (Analysis of the variance of a way) to compare the differences of gender and age in the different variables studied, in addition to post hoc tests, using the Tukey test, to see the differences between the different age groups and anthropometry. In addition, an analysis of the Pearson Correlation Coefficient was performed to fulfill our main objective. In all cases, the level of significance was established at 5% ($p < 0.05$) and all analyzes were performed on the Stata program (Data Analysis and Statistical Software).

Results

Once the tests corresponding to the fieldwork were carried out, the respective analyzes were carried out with the study sample of 300 (181 Women and 119 Men) participants from the city of Cúcuta, Colombia with an average age for both genders of 26 ± 10 years; made up of 60% women and the remaining 40% by men. These participants had an academic level of 58% university, 26% had attended secondary school, 9% were high school graduates, 6% were technical or technological and 1% had only primary school.

The identified risk factors were: arterial hypertension, overweight and/or obesity, diabetes, smoking, family history (Diabetes, acute myocardial infarction and hypertension), alcohol intake and fatty foods. Once the results were analyzed and interpreted, it was determined that there is a higher prevalence of smoking, alcohol intake, overweight and/or obesity in men than in women and that 93% of women eat fast meals several times a month (Table 3).

Variable	Quantity	Female	Male	Average
Total Sample				**300**
Year				**26 ± 10 year**
Gender	300	181	119	100
Ethnicity				
White	170	114	56	56,66
Half Blood	97	51	46	32,33
Afrocolombian	33	16	17	11
Risk Factor				
Smoking	17	3 - 1,6%	14 - 11,7%	5,66
Inhalers	28	11 - 6%	22 - 18,4%	9,33
Alcohol intake	206	114 - 62,9%	92 - 77,3%	10,35
Arterial hypertension	7	4 - 2,20%	3 - 2,52%	2,3
Diabetes Mellitus	3	1 - 0,5%	2 - 1,68%	1
Fatty food intake	279	169 - 93,3%	110 - 92%	93
Family background	91	49 - 27%	42 - 35,2%	30,33
Anthropometry - BMI				
Infrapeso	12	6 - 3,3%	6 - 5%	4
Normal weight	167	109 - 60,2%	58 - 48,7%	55,66
Overweight	88	47 - 25,9%	41 - 34,4%	29,33
Obesity Company	33	19 - 10,5%	14 - 11,8%	11
Education				
Primary	3	1 - 0,55%	2 - 1,68%	1
High school	75	45 - 24,86%	30 - 25,21%	25
Graduated Bachelor	27	13 - 7,18%	14 - 11,76%	9
Technical	12	5 - 2,76%	7 - 5,88%	4
Technological	7	5 - 2,76%	2 - 1,68%	2,33
Undergraduate	164	105 - 58%	59 - 49,57%	54,66
Postgraduate	12	7 - 3,86%	5 - 4,20%	4

Table 3: *Characterization of the population.*

On the other hand, the results obtained in the stress test show similar values for men (179.68 ± 15.17) with respect to women (179.67 ± 15.23) (Table 4) and when comparing the HR_{max} in a test of effort and that found by the equations, an overestimation was observed by the equations up to 14 beats per minute (bpm). The 220-age equation was not found valid or effective when determining HR_{max}; the formula obtained an average error of 14 bpm and the formula by Tanaka., *et al.* 1997 and 2001 obtained an error of 10 and 9 beats per minute respectively.

	Male	Women
Sample	119	181
Media	179,68	179,67
German	15,17	15,23
Maximum Value FCM*	117	133
Minimum Value FCM	210	206

Table 4: *HR_{Max} Results obtained in stress test.*
FCM: Maximum Heart Rate; SD: Standard Deviation

Likewise, the results obtained in the stress test were compared with the 220-Age and 210-Age equations, and as previously mentioned there was 14 bpm difference in the 220-Age formula (Stress test: 179.6 ± 15 vs. Formula: 193.6 ± 10.4) and 4 bpm when comparing the stress test with the 210-Age formula (179.6 ± 15 vs 183.6 ± 10). In addition, the values obtained according to the body mass index and age of the participants were compared with the aforementioned formulas. Proving that the 220-Age formula is older, it presents greater similarity to the results obtained by stress test, as well as a higher Body Mass Index (BMI), lower difference compared to the HR_{max} obtained through an exercise test with Bruce's protocol. And regarding the formula of Tanaka., *et al.* (1997) and (2001) obtained differences of 10 (p = 0.000) and 9 (p = 0.000) beats per minute respectively.

In addition, a Pearson correlation coefficient analysis was performed to make the results obtained more complete, where it was determined that the analyzed formulas have a Pearson's r for 220-Age and 210-Age of r = 0.447 and Tanaka r = 0.451 this being a weak positive correlation. Consequently, it is considered that the equations currently used to estimate the HR_{max} are not accurate to prescribe the ranges of the training heart rate (Table 5).

Study	Formula	Media	HR_{Max}*	DF	r Pearson	Value of p
Tanaka., *et al*. (1997)	211-0.8 * Age	189,95 ± 8,38	179,68 ± 15	10,2 bpm	0,446	0,000
Tanaka., *et al*. (2001)	207-0.7 * age	188,58 ± 7,33	179,68 ± 15	8,9 bpm	0,451	0,000
Tanaka., *et al*. (2001)	206-0.7 * Age	187,58 ± 7,33	179,68 ± 15	7,9 bpm	0,451	0,000
Tanaka., *et al*. (2001)	208,75-0,73 * age	189,54 ± 7,65	179,68 ± 15	9,8 bpm	0,446	0,000
	220-Age	193,69 ± 10,48	179,68 ± 15	14 bpm	0,447	0,000
	210-Age	183,68 ± 10,48	179,68 ± 15	4 bpm	0,447	0,002

Table 5: *Results and difference of stress test versus equations and r-Pearson's.*
**Average general maximum heart rate obtained in stress test.*
DT: Standard deviation; HRMax: Maximum Cardiac Frequency; DF: Difference between result of equations and stress test expressed in beats per minute; bpm: Beats per minute.
P value determined by one-way ANOVA with $p < 0.05$.

Discussion

HR_{max} is often estimated using the Tanaka and/or 220-Age equation, which is not known for sure where it comes from and does not come from a regression analysis. Its use every day has been increasing due to its practicality. However, this practicality is overshadowed by its large margin of error compared to real heartbeats. That is why, after analyzing this research, we agree with many authors [10,14,28-31] when questioning the applicability of the formulas to determine the maximum heart rate.

On the other hand, in an investigation carried out by Garcia-Verdugo Mariano (2013), the 220-Age formula was compared to the DIPER test that responds to the initials of "Determination of Intensities and Potencies for Resistance Training" (García-Verdugo, 2006). Said test consists of an incremental test based on 400-meter sections with decreasing times in different sequences as the athlete approaches his limit and with 30-second pauses. This research correlated with Pearson's R the data obtained with the 220-Age formula and the HR_{max} obtained with the DIPER test in the entire population studied (n = 278). The calculation was made for the totality and for both sexes separately (Men r = 0.24 and Women r = 0.4), concluding that: "It is not useful for predicting the maximum heart rate and, therefore, it would not be useful to establish training power zones based on percentages of said HR_{max} when this is predicted through the application of this equation".

Likewise, a research work [32] compared a test of effort in endless band vs 220-Age and the results of HR_{max} obtained in the test were 185.3 bpm ± 11.3 bpm vs 188.7 bpm ± 12.3 bpm obtained by The equation. Clearly it is observed that the HR_{max} obtained by the formulas, is significantly greater than the real one. These results coincide with the data obtained in the present study, in which the 220-Age equation overestimates the HR_{max} for both men and women.

Other studies [33-35] mention and demonstrate through clinical studies that the equation "220-Age" should not be used as a tool to calculate the HR_{max}, since it is a generator of serious errors when prescribing exercise as well as in patients with heart disease, as in seemingly healthy people; suggestion that is supported by the results presented in this investigation.

At the same time, Agustina-Miragaya M and Federico-Magri O [25] find that the 220-Age formula greatly overestimates the actual HR_{max} and this overestimation is 5 to 35 beats per minute. Regarding the formula of Tanaka., *et al.* the overestimation is from 19 to 25 beats per minute. And compared to Pearson's R correlation compared with the results of the present investigation, it is shown that there was no difference in both studies. The correlation was weak positive (r = 0.342 Vs r = 0.447).

In Brazil [36] they concluded that the equation "220 - age" is not valid or appropriate, like the previous studies, this formula overestimates the results. So despite its extensive application and great recognition, the formula "220-age", requires immediately samples to know its origin, author and age group used for its preparation, since to date is unknown [37,38].

Conclusions

For a proper prescription of the exercise, it is essential to perform a stress test with the Bruce protocol for apparently healthy patients, or Naughton, for elderly or with some degree of alteration that is contraindicated Bruce protocol, to obtain a maximum heart rate real and avoid errors in training planning. The results obtained show differences above 13 beats per minute in the study population; which is a great gap to make an adequate prescription and therefore effective results in our patients; in addition, to mitigate the risk of adverse events due to inadequate prescription.

The need to continue with this research with a greater population and different characteristics to those evaluated, to determine a more exact equation that contemplates different variables or in its effect the creation of an autochthonous equation that meets the characteristics of the region is highlighted.

Conflict of Interest

The authors declare no conflict of interest.

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Volume 5 Issue 10 Octobert 2018