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Reliability Of Maximum Heart Rate Estimation Equations In Athletes In The Field Football Base Category

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Abstract:
The objective of this study was to verify the reliability of the HRmax prediction equations proposed by Fox, Tanaka and Nikolaidis in field football athletes who belong to the youth categories of a club in the first division of Brazilian league. One hundred and sixty-four players, aged between 14 and 20, took part in this study. In order to determine the athletes' HRmax (bpm), Yo-Yo Endurance Test Level 1 was used and defined as the highest value achieved during the test. Data were expressed as mean, standard deviation (SD) of the mean, minimum and maximum values.Independent Student's t-test and Pearson's correlation coefficient were used in statistical analyses. The results showed that none of the three available equations (Fox, Tanaka and Nikolaidis) provide accurate HRmax values in a sample of youth football players, underestimating or overestimating HRmax values. The equation that provided the most accurate HRmax was the Nikolaidis equation. This result is probably due to the fact that this equation was developed based on an example of a football player.
Keywords: *football, heart rate, athletes.*

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I. Introduction:

Football is the most popular sport in the world. The high degree of competitiveness that characterizes the sport has led to several studies to analyze the physical demands of the athletes. In this context, determining the maximum heart rate in football athletes is essential for prescribing and monitoring responses to physical training[1].

Therefore, to control the physical training of the sport, heart rate (HR) intensities are often established by calculating the HRmax using prediction equations[2]. Among these, we can mention the equations of Fox (220-age), Tanaka (208-0.7×age) and Nikolaidis (223-1.44×age)[3-5]. Such formulas are based on the hypothesis that HRmax decreases with aging, due to the reduction in the activity of the autonomic nervous system, responsible for controlling vegetative functions[6].

Although prediction equations are widely used to evaluate the intensity of physical exercise and sport, based on the percentages of HRmax achieved during effort, there is not sufficient and well-founded data to determine the validity of the equations, making it necessary to evaluate specific indices for a given age group, ethnicity, frequency of physical activity, among others[2]. However, these equations are used due to the difficulty of carrying out maximum effort tests, making it sometimes more viable and convenient to use predictive equations[4]. The complications in obtaining the most reliable HRmax percentages with football players are related to training quantification, integrating external stress indicators with internal indicators, there are also variances between the results obtained during training and those obtained during matches[7].

Another issue to be highlighted is that, when evaluating football athletes, it is known that the expected performance provides a high HR, and the average HR of these athletes is rarely less than 65% of the HRmax and can reach peaks around 98% of HRmax during a match[8]. This demonstrates the difference present when analyzing an athlete and a non-athlete, for example, who will have different HRmax due to their habits and living conditions, which makes it difficult to use pre-determined equations.

Therefore, the objective of the present study was to verify the reliability of the HRmax prediction

equations proposed by Fox, Tanaka and Nikolaidis in field football athletes belonging to the youth categories of a club in the first division of Brazilian league.

II. Methodology

Sample

One hundred and sixty-four (164) male football athletes participated in the study, aged between 14 and 20 years old, included in the categories under 14, 15, 16, 17, 19 and 20, all with experience in the sport of at least one year, belonging to the categories of a professional football club that currently participates in series A competitions of the Brazilian championship. The representation by game position was: goalkeepers (n=17); fullbacks (n=25); defenders (n=21); defensive midfielders (n=30); midfielders (n=20); forwards (n=43) and center forwards (n=8).

All categories investigated carried out four training sessions per week, corresponding to eight weekly hours of training, in addition to regional and state competitive games. All data collected during the months of October and November 2023.

Data Collection Procedures

Anthropometric measurements and the application of the aerobic power test were carried out during training sessions at the club by the researchers and technical committee. Height (cm) and body mass (kg) were measured with athletes with no shoes and wearing only shorts. Body mass index was calculated from the quotient between body mass (kg) and height (m) squared.

To determine the HRmax (bpm) and indirectly calculate the VO2max (mm.kg.min-1) of the athletes, Yo-Yo endurance test level 1 was used, a modernized adaptation of the Léger 20 m Shuttle-run test; Lambert9, created by Bangsbo et al.10.

The HRmax prediction equations used were those of Fox (Fox-HRmax = 220-age), Tanaka (Tanaka-HRmax = 208 - 0.7 x age) and Nikolaidis (Nikolaidis-HRmax = 223 - 741.44 x age) 3-5.

All players signed a written consent form and allowed the data to be used for research purposes. The study was approved by the Ethics Committee (CAAE 77 57112616.2.0000.5349).

Statistical Procedures

Statistical analyzes were performed using IBM SPSS v.20.0. Data were expressed as mean, standard deviation (SD) of mean, minimum and maximum values.

The t-Test for paired samples was used to verify possible differences between the measured HRmax and the HRmax predicted from the Fox-HRmax, Tanaka-HRmax and Nikolaidis-HRmax methods. Associations between measured HRmax and predicted HRmax were determined using the Pearson Correlation test (r). The magnitudes of the correlation coefficients were considered trivial if $r \leq 0.1$, small if $0.1 \leq r < 0.3$, moderate if $0.3 \leq r < 0.5$, large if $0.5 \leq r< 0, 7$, very large if $0.7 \leq r < 0.9$, almost perfect if $r \geq 0.9$, and perfect if $r = 1$. The significance level was set at $\alpha = 0.05$.

III. Results

The basic characteristics of the participants are presented in Table 1. The correlation values between the measured HRmax and the predicted HRmax for the age are described in Table 2 and the comparisons between the measured HRmax and the predicted HRmax for the age are in Table 3.

Table 1 - Descriptive characteristics, presented as mean, standard deviation, with minimum and maximum number of athletes

Variable	Mean ± Standard Deviation	Minimum	Maximum
Age (years)	17,05 ± 2,06	14	20
Body weight (kg)	67,37 ± 9,52	40,6	95,7
Body height (cm)	176,61 ± 8,10	155,2	201,0
BMI (kg/m^2)	21,50 ± 1,91	16,78	26,17
Fat percentage (%)	10,86 ± 1,19	8,9	15,3
Percentage of muscle mass (%)	47,46 ± 1,48	43,2	50,3
VO2máx (ml.kg^{-1}.min^{-1})	54,44 ± 5,07	35,2	68,7

Table 2. Correlation values between measured HRmax and predicted HRmax for age

	n	Correlation	Sig.
Measured HRmáx and Fox-HRmáx	162	0,444	0,001
Measured HRmáx and Tanaka-HRmáx	162	0,447	0,001
Measured HRmáx and Nikolaids-HRmáx	162	0,458	0,001

There are significant correlations between measured HRmax and predicted HRmax for age ($p = 0.001$)

regardless of the equation used, with the magnitude of the correlation being considered moderate (r = 0.458).

Table 3 - Comparison of measured HRmax and predicted HRmax for the age of the different equations analyzed

Mean ± Standard Deviation		*t*	Sig.
Measured HRmáx (bpm) Fox-HRmáx (bpm)	199,89 ± 6,58 202,97 ± 2,06	-6,625	0,001
Measured HRmáx (bpm) Tanaka-HRmáx (bpm)	199,89 ± 6,58 196,08 ± 1,44	7,994	0,001
Measured HRmáx (bpm) Nikolaids-HRmáx (bpm)	199,89 ± 6,58 198,48 ± 2,96	3,055	0,003

There are significant differences between the measured HRmax and the HRmax estimated by the Fox (p=0.001), Tanaka (p=0.001) and Nikolaidis (p=0.003) equations.

IV. Discussion

The present study aimed to verify the reliability of the maximum heart rate (HRmax) prediction equations proposed by Fox, Tanaka and Nikolaidis in field football athletes belonging to the youth categories of a club in the first division of Brazilian football league. The results indicated that there are significant differences between the measured HRmax and the HRmax estimated by the different equations used, suggesting that these equations may not be suitable for this specific group of young high-performance athletes. With technological advances in contemporary society, access and handling of performance variables and training load have been intensified in the sports community, aiming to improve the functions for which they are training (SOARES; TOURINHO FILHO, 2006). Therefore, the evaluation of physiological and metabolic statistics is fundamental for the logistics of carrying out training.

The specialized study of physiological aspects is important for building performance in addition to knowing the metabolic demands of the sport. These variables are applied in the prediction models developed by Fox, Tanaka and Nikolaidis for maximum HR, which do not present 100% reliability, as they disregard environmental and daily life aspects which allow the occurrence of errors when such estimation is treated individually (HÉLCIO & Reeberg Stanganelli, 2015).

Studies show the influence of psychological variables on the cardiovascular response presented during exercise, such as pre-competition anxiety and depression (MEN LIPP, 2007). Furthermore, the training environment, encompassing both climatic conditions and site characteristics, can affect the athlete's physiological response. These factors can induce variables not covered by the previously mentioned conventional prediction equations. For that reason, the exclusion of these elements in traditional prediction models can result in inaccurate estimates of maximum HR (GG ARAÚJO, 1302006)

There are differences between the average measured HRmax and the average predicted HRmax for the expected age. Therefore, it is suggested that the choice of equation may affect the accuracy of HRmax estimation based on age. The Fox-HRmax equation ends up overestimating HRmax, while the Tanaka-HRmax equation tends to reduce it in comparison to the measured HRmax. The Nikolaidis-HRmax equation presents a smaller underestimation compared to the measured HRmax11.

These equations are associated with the same physiological principle, which tends to demonstrate that heart rate normally decreases as individuals age, most likely due to hypoactivity of the organism (TIBANA, Ramires Alsamir et al). Despite this, they differ in results and factors that lead to changes in HR, and it is extremely important to highlight the possibility of error that they present. Therefore, there is no agreement in the literature that says which index is the best.

There are many factors that can influence the measurement of HRmax that are not considered by the Tanaka-HRmax, Nikolaidis-HRmax and Fox-HRmax equations, such as physical conditioning, body mass, eating habits, among other things (TIBANA, Ramires Alsamir et al) . Therefore, it can be seen that these indices can often overestimate the subject's HR, triggering many disputes about their accuracy.

In this sense, the use of regressions to indirectly estimate HRmax on the cycle ergometer for individuals who are not in good physical condition potentially increases the HRmax prediction error and, consequently, the exercise intensity to be performed, a fact that suggests that HRmax should be determined directly for each individual (Karvonen JJ).

According to the results obtained, the three equations used resulted in an estimated HRmax

significantly different from that found when the HRmax was measured, demonstrating their divergences and inconsistencies with the authenticity.

According to Almeida et al, predictive equations are valid when applied to populations with characteristics similar to those of the sample from which the equation was generated. Therefore, the Fox and Tanaka equations should not be used when the objective is training athletes.

V. Conclusion

Our results showed that the reliability of the HRmax prediction equations proposed by Fox, Tanaka and Nikolaidis are not satisfactory for a proper statistical result, as there are divergences between the measured HRmax indices and the estimated HRmax. It is clear that, to obtain an adequate prognosis of HRmax in athletes, especially high-performance athletes, predictive equations are not sufficient.

Considering the different possibilities for applying HRmax measurement and its interpretation, we should consider that strategies for using HRmax as a diagnostic, a prognostic tool or even for exercise prescription, should be based, whenever possible, on directly collected data, in order to reduce the risks and mistakes of its interpretation and, on the other hand, enhance its application.

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