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Comparison between Age-Predicted and Measured Maximal Heart Rate in Professional Soccer Athletes

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Abstract The aim of this study was to compare the measure maximal heart rate (measure-HR_{max}) available in maximum treadmill test with age-predicted-HR_{max} from the Karvonen (Fox-HR_{max}), Tanaka (Tanaka- HR_{max}) and Nikolaidis (Nikolaids-HR_{max}) methods. Ninety players, aged 16 and 33 years, a first division club of Brazilian football participate in this study. A Bruce protocol was used in the treadmill to assess the maximal aerobic running speed. Measured-HR_{max} was defined as the highest value attained during the test. Data were expressed as mean, standard deviation (SD) of the mean, minimum and maximal values. Independent Student's t-test, Bland-Altman analysis and Pearson's correlation coefficient was using in statistical analyses. Our results showed that none of the three available equations (Fox, Tanaka and Nikolaids) provides accurate values of HR_{max} in a sample of professional soccer players. The three equations overestimated measure-HR_{max}. However, the equation that provided the most accurate measured-HR_{max} was the Nikolaids equation. This is true probably to the fact that this equation has been developed from a sample soccer player.

Keywords Soccer, Heart Rate, Athletes

1. Introduction

The heart rate (HR) is a non-invasive marker often used for prescribing exercise and training [1]. Variability and application in sport has been extensively studied in recent years [2-4]. Although the HR is a seemingly simple data to be gathered during exercise it can be evaluated according to several methods and measurement at different times during the effort. The HR measurement can generate a large number of indexes, each with its pros and against, which should be considered in the monitoring of different sports and athletes.

According Nikolaidis [5], the age-predicted maximal heart rate (age-predicted-HR_{max}) is the most commonly used by coaches and trainers. In soccer we usually use this method of estimation of HR_{max} even in different intensities of training.

Bangsbo et al [6] states that the average HR of a football player is rarely less than 65% of HR_{max}, and can reach peaks of around 98%. However, the intensity average value measured as a percentage of HR_{max} is approximately 85%. In this sense, the optimization of the training should take into consideration the workload in order to optimize the adjustments to improve the performance [7]. Buchheit [1] reported that to quantify the amount of training the integration of external stress indicators with internal indicators are required. These data should be recorded along the training session in order to obtain composite measurements of training load.

Several equations have been proposed in order to age-predicted-HR_{max}, because the maximal exercise test is not always feasible [8]. These equations leave the physiological assumption that the HR_{max} tends to decrease with aging, possibly due to a lower activity autonomic nervous system [9]. In addition to the equation 220 - age [10], another widely used equation is the 208 - 0,7 x age [6]. The latter has showed to provide a greater accuracy in age-predicted-HR_{max}, based on the results of a meta-analysis combined with a cross-validation study. More recently Nikolaidis [11] proposed the equation 223 - 1,44 x age after evaluating 162 adolescents (age = 15.8 ± 1.5 years) and 158 adults (age = 23.4 ± 4.6 years) all football players tied to competitive clubs.

Therefore, the aim of this study was to compare the measure maximal heart rate (measure-HR_{max}) available in maximum treadmill test with age-predicted-HR_{max} from the Karvonen (Fox-HR_{max}), Tanaka (Tanaka- HR_{max}) and Nikolaidis (Nikolaids-HR_{max}) methods.

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2. Material and Methods

Ninety players, aged 16 and 33 years, a first division club of Brazilian football participate in this study. Weight (kg) and height (cm) were measured with subjects in minimal clothing and barefoot. Body mass index was calculated as the quotient of body mass (kg) to height squared (m^2).

A Bruce protocol was used in the treadmill to assess the maximal aerobic running speed as previously described [12]. The treadmill used was a multiprogram treadmill by Inbramed, model KT 10200 ATL. Measured-HRmax was defined as the highest value attained during the test. HR was recorded continuously during the test by Team2 Pro (Polar Electro Oy, Kempele, Finland).

Statistical analyses were performed using IBM SPSS v. 20.0. Data were expressed as mean, standard deviation (SD) of the mean, minimum and maximal values. Independent Student's t-test was used to examine the differences between measure-HR_{max} and age-predicted-HR_{max} from the Fox-HR_{max}, Tanaka- HR_{max} and Nikolaidis-HR_{max} methods. Bland-Altman analysis was used to examine the accuracy and variability of prediction equations. Associations between measured HR_{max} and age were determined using Pearson's product moment correlation coefficient (r). Magnitude of correlation coefficients was considered as 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 $0.7 \leq r < 0.9$, nearly perfect if $r \geq 0.9$, and perfect if $r = 1$. The level of significance was set at $\alpha = 0.05$.

Our local ethical research committee approved the protocol for the study and it is in agreement with the Helsinks'declaration (CAAE: 57112616.2.0000.5349).

3. Results

The basic characteristics of the participants are presented in Table 1. The measured-HR_{max} and age-predicted-HR_{max} correlation values are described in Table 2 and comparisons between the measured-HR_{max} and age-predicted-HR_{max} are in Table 3.

Table 1. Descriptive characteristics, show as mean, standard deviation, with minimum and maximum of the athletes

Variable	Mean ± SD	Minimum	Maximum
Age (years)	22,18 ± 4,37	16	33
Weight (kg)	75,41 ± 6,72	59,0	100,0
Height (cm)	180,13 ± 6,06	165,0	199,0
BMI (kg/m^2)	23,23 ± 1,57	17,70	27,46
Test Duration (min.)	16,05 ± 2,67	11,00	23,36
VO_2máx (ml.kg^{-1}.min^{-1})	58,62 ± 8,01	43,50	87,19

Table 2. Measured-HR_{max} and age-predicted-HR_{max} correlation values

	N	Correlation	Sig.
Measured-HR_{max} and Fox-HR_{max}	90	0,345	0,001
Measured-HR_{max} and Tanaka-HR_{max}	90	0,345	0,001
Measured-HR_{max} and Nikolaids-HR_{max}	90	0,345	0,001

There are statistically significant correlations between measured-HR_{max} and age-predicted-HR_{max} by different equations used, and the values are identical regardless of the equation and moderate (r = 0.345).

Table 3. Comparison of measured-HR_{max} and age-predicted-HR_{max} from the different analyzed equations

	Mean ± SD	*t*	Sig.
Measured-HR_{max} (bpm) Fox-HR_{max} (bpm)	188,61 ± 11,21 197,82 ± 4,37	-8,295	0,000
Measured-HR_{max} (bpm) Tanaka-HR_{max} (bpm)	188,61 ± 11,21 192,47 ± 3,06	-3,474	0,001
Measured-HR_{max} (bpm) Nikolaids-HR_{max} (bpm)	188,61 ± 11,21 191,06 ± 6,29	-2,155	0,034

There are statistically significant differences between Measured-HR_{max} and Fox-HR_{max} (p=0,000), Tanaka-HR_{max} (p=0,001) and Nikolaids-HR_{max} (p=0,034).

Figure 1 show the Bland-Altman plots of the differences between predicted-HR_{max} and measure-HR_{max} for Fox-HR_{max} (BIAS=3,9), Tanaka-HR_{max} (BIAS=3,9) and Nikolaidis-HR_{max} (BIAS=2,5), respectively. In the case of Fox- equation, we observed that there was overestimation of HR_{max}. A similar trends was also noticed in the case of Tanaka and Nikolaidis equations.

4. Discussion

HR_{max} at a given age is frequently estimated by the 220 - age formula. This is usually implemented in nearly all commercial equipment for cardiac stress testing. However, the validity of this formula has often been questioned [8, 13]. According Tibana et al [14], the formula 220 - age has a tendency to overestimate HR_{max} in young subjects and underestimate her in the elderly. However, according Caputo et al [15], the proposed equation by Tanaka et al [8] overestimate the HR_{max} whit respect to the measured end of a maximal exercise test.

Several studies have been produced with different populations. From a sample of 11 physical educations students, aged 18 and 26 years, Vasconcelos [16] identified HR_{max} responses similar to using the Fox equation but not from the equation proposed by Imbar et al [17]. Cleary et al [18] when evaluating the HR_{max} of 96 students healthy volunteers, and compared with 7 age-predicted-HR_{max} equations concluded that the Gellish2 and Fairbarn equations were the most accurate of the age-predicted-HR_{max} equations in a college-age population.

Petto et al [19], compared age-predicted-HR_{max} against the one obtained in the 220 - age formula showing that it overestimates measured-HR_{max} when using the maximal aerobic test whit Bruce protocol. When evaluating 35 indoor soccer athletes of booth sex, Souza et al [20], did not find significant correlations between measured-HR_{max} and Fox-HR_{max}, Tanaka-HR_{max} and Nikolaids-HR_{max}. With 23 individuals, handball practitioners, age 12 and 14, Tibana et al [14] identified significantly smaller measured-HR_{max} values than those age-predicted-HR_{max} from the Tanaka-HR_{max} and HR_{max} predicted by the American College of Sports Medicine equation.

Examining the relationship between HR_{max} and age in 3320 healthy men and women within a wide age range using data from the HUNT Fitness Study (2007–2008), Nes et al [21], the Fox-HR_{max}, Tanaka-HR_{max} and the female-based equation by Gulati-HR_{max} underestimated measured-HR_{max} in the present population. Camarda et al [22], to evaluate 1091 results of HR_{max} of sedentary males and 956 females reported that the Karvonen and Tanaka's equations are similar to the HR_{max} prediction and show good correlation with measured-HR_{max}.

However, few studies have been directed to soccer players. A sample of 162 adolescents (15,8±1,5 years) and 158 adults' (23,4±4,6 years) players, Nikolaidis [11] identified in the total sample, Fox‑HR_{max} overestimated measured‑HR_{max}, while Tanaka‑HR_{max} underestimated HR_{max}. In adolescents, Fox‑HR_{max} overestimated measured‑HR_{max} and Tanaka‑HR_{max} underestimated HR_{max}. In adults, Tanaka‑HR_{max} underestimated HR_{max}, while there was not any difference between Fox‑HR_{max} and measured‑HR_{max}. Nikolaidis [23] in another study, when evaluating young soccer players together with athletes from other sports (futsal, basketball and water polo), all members of competitive clubs, identified Fox-HR_{max} and Nikolaidis-HR_{max} overestimated measured-HR_{max}, while Tanaka-HR_{max} underestimated.

The results of this study differ somewhat from the studies cited, given that the Fox-HR_{max} [9,21 bpm (-16; 63)], Tanaka-HR_{max} [3,86 bpm (-21,70; 58,50)] and Nikolaidis-HR_{max} [2,45 bpm (-22,24; 55)] equation overestimated the HR values when compared to the measured-HR_{max}. The important practical implications are to recognize the risks that coaches and fitness trainers undertake depending on which their choice of prediction equation is. Using Fox, Tanaka or Nikolaidis equation, which tend to overestimate HR, might result in prescribing high exercise intensity.

According Sarzynski [24], a true maximal exercise test is the gold standard measure of maximal aerobic power compared with symptom-limited and submaximal/predictive tests. According Spina et al [25], a decrease in HR_{max} as a direct result of training. However, a decrease in HR_{max} as a result of training is inconsistent among athletes [26]. This seems to be an relevant issue with important practical implications because we need to recognize the risks that coaches and fitness trainers undertake depending on which is their choice of maximal HR prediction equation is.

The main limitation of this study is the wide range of ages in on sample is due to the fact that Brazilian Football Confederation (CBF) in its National Regulation of Registration and Transfer of Athletes [27] recognizes as a professional player those with a minimum age of 16 and this happened in one of our athletes. This range may preclude the full accuracy for the use of these formulas to predict what is supposed to be the estimated target HR for our sample. Also the size of your population may limit the strength of our rusts.

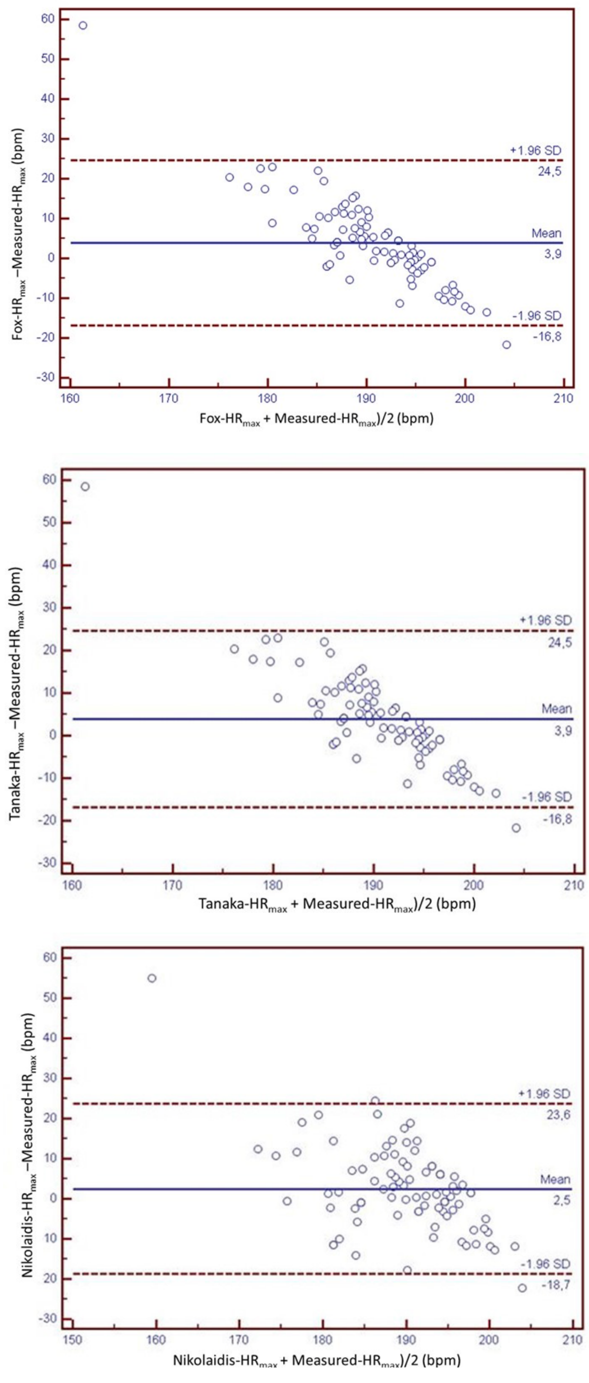

Figure 1. Bland-Alman plots of the difference between Fox-HRmax (A), Tanaka-HRmax (B) and Nikolaidis-HRmax (C) and Measured-HRmax

5. Conclusions

Our results showed that none of the three available equations (Fox, Tanaka and Nikolaids) provides accurate values of HR_{max} in a sample of professional soccer players. The three equations overestimated measure-HR_{max}. However, the equation that provided the most accurate measured-HR_{max} was the Nikolaids equation. This is true probably to the fact that this equation has been developed from a sample soccer player.

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